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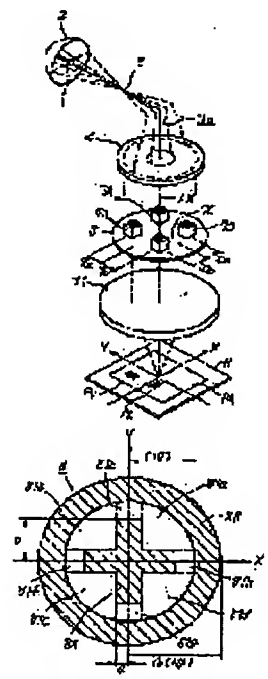
(54) PROJECTION ALIGNER

(57)Abstract:



PURPOSE: To prevent the image-formation performance with reference to an inclined pattern, especially the improvement degree of the depth of focus, of an aligner from being deteriorated by a method wherein, although many optimized parts are included in longitudinal and transverse patterns on a reticle as the light-source shape of a deformed light source, some optimum parts are also included in the inclined pattern.

CONSTITUTION: The shape of a light-shielding plate 8 includes a surface light- source part which is effective in forming the image of slightly inclined patterns Ta, Tb, and the greater part of a central crossed light-shielding part shields a surface light-source part which is not suitable for not only a longitudinal pattern Pv and a groove pattern Pb but also the inclined patterns Ta, Tb. As a result, when the image of the inclined patterns Ta, Tb is formed, a resolution and a depth of focus which are remarkably higher than those by an ordinary illumination (a simply circular or polygonal surface light source using an optical axis AX as the center) in conventional cases can be obtained. Consequently, it is possible to prevent the image-formation performance with reference to the inclined patterns, especially the improvement degree of the depth of focus, of the aligner from being deteriorated.

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CLAIMS

[Claim(s)]
[Claim 1] In the projection aligner equipped with the illumination system which illuminates the mask with which the pattern which should be projected was formed, and the projection optics which projects the image of said pattern on a sensitization substrate said illumination system The illumination-light study system which has the field which serves as relation of the Fourier transform optically to the pattern side of said mask inside, the optical part construction which distributes the illumination light in the predetermined radius centering on an optical axis on said Fourier transform side or its near side -- a law -- a means -- containing -- optical; this construction [part] -- a law -- a means, while distributing said illumination light in the field of the shape of zona orbicularis of the predetermined width of face centering on said optical axis The projection aligner characterized by distributing said illumination light over the field of discrete two or more parts except the core inside the field of the shape of this zona orbicularis.
[Claim 2] The light source for irradiating the illumination light at the mask with which the pattern which should be projected was formed, The illumination-light study system from which the field which serves as relation of the Fourier transform optically to the pattern side of said mask is formed in the interior, and the secondary light source of said light source is made by this Fourier transform side or its near side, In the projection aligner equipped with the projection optics which carries out incidence of the light from the pattern of said mask irradiated by the illumination light from this illumination-light study system, and carries out image formation projection of the image of this pattern on a sensitization substrate The 1st pattern configuration where the pattern on said mask has periodicity in each of the 2-way which intersects perpendicularly mutually, When there are more rates that it is formed in the 2nd pattern configuration which has periodicity in the direction which intersects each of this 2-way, and said 1st pattern configuration closes on said mask than the rate that said 2nd pattern configuration closes, So that the oblique illumination light corresponding to the direction of the periodicity of the configuration of said 1st pattern may be made Said Fourier transform side or the 1st setting member which sets the 1st surface of light source as each of four fields in which eccentricity only of the specified quantity is carried out, and it is mutually located symmetrically from the optical axis of said illumination-light study system on the near side, So that the oblique illumination light corresponding to the direction of the periodicity of said 2nd pattern configuration may be made It has said Fourier transform side or the 2nd setting member which sets the 2nd surface of light source as each of four fields in which eccentricity only of the specified quantity is carried out, and it is mutually located symmetrically from the optical axis of said illumination-light study system on the near side. The projection aligner characterized by making area of said 1st surface of light source larger than the area of said 2nd surface of light source.
[Claim 3] Said 1st setting member and 2nd setting member are equipment given in the 2nd term of a claim characterized by what the transparency section configuration of the gobo arranged in the Fourier transform side or its near side of said illumination-light study system prescribed.
[Claim 4] Said illumination-light study system is equipment given in the 3rd term of a claim characterized by having arranged said gobo to the injection side side of this fly eye lens including the fly eye lens which makes said surface of light source.
[Claim 5] The 1st pattern configuration formed in the 2-way which intersects perpendicularly on a mask with periodicity, The projection optics which carries out image formation projection of the 2nd pattern configuration which has periodicity in the other direction on a sensitization substrate, While making the image formation of the light source image by the fly eye lens which forms the light source image of the magnitude which carries out

incidence of the light from the light source, and is included by the circular field of a predetermined radius, and this fly eye lens carry out in the center of the pupil surface of said projection optics, or its near side In the projection aligner equipped with the condensing optical system on which the light from each point in said light source image is made to superimpose on said mask When two axes of coordinates corresponding to each of the 2-way which intersects perpendicularly mutually among the directions of the periodicity of said pattern by making the core of said light source image into a zero are set up, this -- with the 1st transparency section which four quadrants specified with two axes of coordinates were alike, respectively, and was mostly formed in the same area Mostly from said zero in an equidistant location to each four on said two axes of coordinates The projection aligner characterized by having arranged the gobo which has the 2nd transparency section mostly formed in the same area to the injection side of said fly eye lens, and changing the area of the 1st transparency section of said gobo, and the 2nd transparency section according to the significance of said 1st pattern configuration and 2nd pattern configuration.

[Claim 6] Incidence of the light from the light source is carried out to the projection optics which carries out image formation projection of the pattern of a mask on a sensitization substrate. In the projection aligner equipped with the illumination-light study system which forms the surface light source of a predetermined configuration in the optical Fourier transform side over said mask, or its near side, and irradiates the light from this surface light source uniformly on said mask When r and the coherence factor of said surface light source are made into a sigma value for the radius of the circle which defined the rectangular coordinate system XY and was approximated to the appearance of said surface light source by making the core of said surface light source into a zero, It is each about multipliers a and b. 0.1 r/sigma<=a <= 0.4 r/sigma As 0.4 r/sigma<=b <= 0.8 r/sigma The projection aligner characterized by preparing the optical intensity-distribution controller material which makes optical reinforcement with the inside of the field of -a<=X<=a, the inside of the field of -b<=Y<=b and -a<=Y<=a, and -b<=X<=b smaller than other fields on said surface light source, or is set to about 0.

[Claim 7] Said optical intensity-distribution controller material is a multiplier c. When it considers as 0.3 r/sigma<=c <= 0.6 r/sigma, it is X2+Y2 <=c2 on said surface light source. Equipment given in the 6th term of a claim characterized by making optical reinforcement in a field smaller than other fields, or being referred to as about 0.

[Claim 8] said illumination-light study system is constituted so that image formation of the zero of said surface light source may be carried out to the core of the pupil surface of said projection optics -- having -- the radius on said surface light source of the effectual pupil diameter of this projection optics -- r0 ** -- the time of carrying out -- a ratio with the radius r of said surface light source -- r/r0 it is -- equipment given in any 1 term of the 6th term of a claim characterized by making a sigma value or more into 0.7, or the 7th term

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the aligner which devised to the lighting of the mask (reticle) with which the pattern which should be imprinted especially was formed about the projection aligner used for the exposure imprint of detailed patterns, such as a semiconductor integrated circuit and a liquid crystal display component.
[0002]
[Description of the Prior Art] In the lithography process to which detailed-ization progresses every year, installation of the practical projection aligner for current and 64 MD-RAM manufacture is indispensable. In order to attain the projection exposure imprint of such a detailed pattern in sufficient precision, more various devices than before are proposed. among those, the pattern which should be imprinted especially also came periodicity in a certain direction suddenly like Rhine - and - tooth space (it considers as L&S below), it was alike, and super resolution techniques, such as JP,4-108612,A and JP,4-225514,A, were proposed as technique to which resemble markedly rather than before and resolution and the depth of focus are made to expand.
[0003] This super resolution technique is making special only the orientation property of the illumination light to the mask substrate (reticle) with which the L&S pattern which should carry out projection exposure was formed, and makes the detailed pattern which was not resolved resolve with sufficient depth of focus in the conventional lighting. The orientation property of the illumination light is made by controlling distribution of the illumination-light bundle in the Fourier transform side over the reticle in an illumination-light study system, i.e., distribution of secondary light source images, corresponding to whenever [of the pattern of L&S of a reticle / detailed] (pitch etc.).
[0004] Drawing 1 is the perspective view showing the typical configuration of the illumination-light study system which applied the technique indicated by the above-mentioned official report. Here, the point of this mercury lamp 1 emitting light is arranged to the 1st focus of the ellipse mirror 2, using a mercury lamp 1 as a source of the illumination light. Once converging the illumination light ILa reflected in the ellipse mirror 2 with the 2nd focus 3, it is reflected by the non-illustrated mirror and incidence of it is carried out to the collimator lens system 4. When the ellipse mirror 2 and a mercury lamp 1 are generally combined like drawing 1 , the cross section of the illumination light ILa has zona-orbicularis-like (shape of doughnut) intensity distribution. The illumination light ILa of the cross section of the shape of this zona orbicularis is mostly changed into the parallel flux of light by the collimator lens system 4, and reaches the gobo 8 arranged in the Fourier transform side within an illumination system. On a gobo 8, four openings are prepared from an optical axis AX in an equidistant location, and the fly eye lenses 7A, 7B, 7C, and 7D are formed in each of this opening. Each of each plane of incidence of these fly eye lenses 7A-7D is located in the illumination-light bundle ILa of a zona-orbicularis-like cross section. Moreover, the point light source image of a mercury lamp 1 is formed in each injection side of the fly eye lenses 7A-7D only several minutes of the element lens in the fly eye lens. Therefore, secondary light source images (surface light source) are formed in each injection side of the fly eye lenses 7A-7D.
[0005] The illumination light from each of each fly eye lenses 7A-7D is uniformly superimposed on the pattern formation field PA of Reticle R, and is irradiated by the inverse Fourier transform optical system 11 (it is henceforth called a condenser lens for convenience) containing a condenser lens etc. When Reticle R is arranged and the core is made into the zero of system of coordinates XY so that an optical axis AX may pass at

the core of pattern space PA of Reticle R, in many cases, a L&S-like reticle pattern is divided into the L&S pattern (vertical pattern) Pv which has a pitch in the direction of X, and the L&S pattern (horizontal pattern) Ph which has a pitch in the direction of Y. That is, in pattern space PA, a pattern group with periodicity is gathered and formed about the 2-way of the direction of X, and the direction of Y.
[0006] If lighting conditions shall be optimized to the minimum thing among X of the L&S patterns Pv and Ph, and the pitch of the direction of Y, eccentricity yalpha from each optical axis AX of the fly eye lenses 7A-7D and xbeta will be decided by the minimum pitch of the L&S pattern, and the most important relation. The wavelength of Gy (micrometer) and the illumination light ILa for the minimum pitch of the direction of Y of the L&S pattern Ph For example, lambda (micrometer), When the distance from a condenser lens 11 to Reticle R, i.e., a focal distance, is set to f (mm) and the angle of diffraction (include angle from zero-order light) of the primary diffracted light generated from the L&S pattern Ph is set to 2thetay (rad), Eccentricity yalpha of the direction of Y of one fly eye lens to which its attention is paid is decided that sin2theta y=lambda/Gy and y alpha=f-sin theta y are mostly filled by coincidence.
[0007] Furthermore, it is decided that sin2theta x=lambda/Gx and x beta=fsin theta x are mostly satisfied with coincidence of eccentricity xbeta of the direction of X of one fly eye lens to which its attention is paid when the minimum pitch of the direction of X of the L&S pattern Pv is set to Gx (micrometer) and the angle of diffraction of the primary diffracted light generated from the L&S pattern Pv is set to 2thetax (rad). as mentioned above, in the conventional special illumination (deformation light source) For super resolution projection of Pattern Pv which has a pitch in the direction of X among the L&S patterns on Reticle R The pair of secondary light source images which carried out eccentricity in the direction of X symmetrically on the Fourier transform side (7 D with fly eye lens 7A) or for super resolution projection of Pattern Ph which the oblique illumination light from the fly eye lenses 7B and 7C contributes, and has a pitch in the direction of Y The oblique illumination light from the pair (the fly eye lenses 7A and 7B or fly eye lenses 7C and 7D) of secondary light source images which carried out eccentricity symmetrically contributes in the direction of Y on a Fourier transform side.
[0008] In addition, the rotary shutter which controls initiation and interruption of exposure to the 2nd focus 3 in drawing 1 is arranged, the 2nd focus 3 is secondary light source images and conjugation which are formed in each injection side side of the fly eye lenses 7A-7D, and each plane of incidence of the fly eye lenses 7A-7D has become conjugate [of Reticle R / the pattern side and conjugate].
[0009]
[Problem(s) to be Solved by the Invention] In the conventional technique like the above, it is effective in improving resolution and the depth of focus about the specific direction of the circuit original edition (reticle) which should be imprinted, for example, the periodic pattern of a 2-way which intersects perpendicularly. however, about the pattern which has periodicity in other directions, especially the direction which the 2-way the 2-way and the above cross at right angles boiled, respectively, and it received and was rotated 45 degrees, there was a problem that resolution and the depth of focus fell rather than the aligner which applied the usual illumination.
[0010] these aim at offer of the projection aligner with which high resolving and large focus depth are obtained from usual equipment also with the slanting (for example, 45-degree rotation) pattern with which directions differ, accomplishing this invention in view of such a problem, and raising sharply the resolution of the 2-way pattern which is alike, respectively and has periodicity of the direction [parallel to especially a reticle appearance] in every direction on a reticle, and the depth of focus.
[0011]
[Means for Solving the Problem] The two-dimensional configuration of the light source image (surface light source) formed in the Fourier transform side in the illumination-light study system for the mask lighting of a projection aligner is applied to the conventional configuration, and it was made to deform it a little in this invention. It is made for the zona-orbicularis part outside the circle C2 of a predetermined radius not to specifically shade at all from a zero among the surface light sources (here injection side of the fly eye lens 7) included in the almost circular field C1, as shown in drawing 2 . And cross-joint-like protection-from-light section 8A prolonged in each of X and the direction of Y from the zero is prepared inside a circle C2, and the transparency section (surface of light source) mutually divided into each of four quadrants specified with X and a Y coordinate shaft was formed. The transparency section of the four quadrants contributes to the super

resolution of a periodicity pattern which has a pitch in each of X and the direction of Y as usual.
[0012] Although all of four points of cross-joint-like protection-from-light section 8A were installed in the former beyond the radius (almost radius of a circle C1) of the surface light source, four points of the cross-joint-like protection-from-light section 8 are made smaller than the radius of the surface light source, and it was made for the surface light source small in area to exist also in the outside of these four points in this invention. In addition, a setup of the rectangular coordinate system XY in this drawing 2 is completely the same as the thing of drawing 1 R> 1, and the zero of system of coordinates XY is in agreement with the optical axis AX of an illumination-light study system or projection optics. Moreover, in drawing 2 , EP expresses the pupil surface of the projection optics seen in the injection side of the fly eye lens 7 as a two-dimensional light source image (surface light source).
[0013] Generally with this kind of projection aligner, a surface light source image (image of the injection side of the fly eye lens 7) is formed in the pupil surface (Fourier transform side) of projection optics. and radius r0 of the pupil EP of the projection optics seen on the Fourier transform side in an illumination-light study system a ratio with the radius r of the surface light source -- r/r0 Things are called a sigma value. Then, if 0.7 to about 0.8 and radius r' of a circle C2 are made into 0.64r0=0.64 r/sigma extent for the radius of a circle C1 by the sigma value in drawing 2 , the effectiveness of super resolution will fully come to be acquired also to a periodic pattern with a line breadth of 0.4-0.45 micrometers which has a pitch in the direction rotated only 45 degrees to each of X and the direction of Y. In addition, about the setups of circles C1 and C2 and the dimension conditions of cross-joint-like protection-from-light section 8A which were shown in drawing 2 , it illustrates in a detail in future examples.
[0014]
[Function] While many parts optimized by the pattern in every direction on a reticle were included as the so-called light source configuration of the deformation light source, it was made to also include slightly the part (outside at the tip of cross-joint-like protection-from-light section 8A of drawing 2) optimal also about a slanting pattern in this invention. For this reason, in the conventional deformation light source, the resolution and the depth of focus of a slanting pattern which had usually got worse from lighting rather are also usually improvable compared with lighting. Moreover, since the balance of the area (quantity of light) of the light source section optimized by the pattern in every direction and the area (quantity of light) of the light source section optimized by the slanting pattern is also optimized, an improvement of the resolution at the time of projection of a pattern in every direction and the depth of focus can also be realized almost to the same extent as the case of the conventional deformation light source configuration. In addition, when the zona-orbicularis-like surface light source section (radius r'-r) is prepared in the outside of cross-joint-like protection-from-light section 8A like drawing 2 , even if the direction of the periodicity of a slanting pattern is not necessarily 45 degrees (or 135 degrees) to each of X and the direction of Y, the effectiveness of this invention is acquired.
[0015]
[Example] Drawing 3 is drawing showing the overall outline configuration of the projection aligner by the example of this invention. And the same sign is given to the thing in drawing 1 , and the thing of the same function by the member in drawing 3 . After converge of the illumination light ILa from a mercury lamp 1 is carried out to the 2nd focus 3 in the ellipse mirror 2, incidence of it is carried out to the fly eye lens 7 through the collimator lens system 4, a mirror 5, and the input side field lens 6. Rotary shutter 19A which rotates to an one direction is arranged in the location of the 2nd focus 3, and shutter 19A is controlled by drive unit (motor, drive circuit, etc.) 19B. Moreover, in case incidence of the illumination light ILa is carried out to the fly eye lens 7, it has zona-orbicularis-like intensity distribution like the case of drawing 1 , but it is suitable for the case, although the configuration of a gobo (diaphragm) 8 prepared in the injection side of the fly eye lens 7 makes the deformation light source like drawing 2 R> 2. However, when switching a gobo 8 to the gobo 9 with the same circular aperture diaphragm as usual and usually illuminating, the intensity distribution of the shape of zona orbicularis of the illumination light ILa are not so desirable. In the case of that to which especially the reticle R applied the phase shift method, the numerical aperture of the illumination light to Reticle R is extracted to a comparatively small value (it is 0.2 to about 0.4 at a sigma value). In that case, only the light of the center section of the intensity distribution of the shape of zona orbicularis of the illumination light ILa from the element lens of the central part of the fly eye lens 7, i.e., the illumination light, will be used for reticle lighting, and will cause an illuminance fall.

[0016] then, the time of usually changing to lighting -- for example, -- USP.4,637,691 etc. -- it is good to arrange the prism 30 which is indicated exchangeable between a collimator lens 4 and the field lens 6, and to operate the intensity distribution of the shape of zona orbicularis of the illumination light ILa orthopedically to distribution of a circle configuration. Now, the turret 10 which holds the gobo 8 and the gobo 9 usually for the light sources for the deformation light sources like drawing 2 exchangeable is formed in the injection side of the fly eye lens 7. A turret 10 is rotated by drive unit 10A for every predetermined include angle. In drawing 3 , the gobo 8 is positioned at the injection side of the fly eye lens 7. In this way, incidence of the illumination light ILb which passed along the transparency section of a gobo 8 is carried out to a condenser lens 11 through the output side field lens 13 and a mirror 12. The light from each point light source of two or more element lenses out of which it was chosen in the fly eye lens 7 is altogether superimposed on the pattern space of Reticle R, and is uniformly irradiated by the condenser lens 11. The illumination light ILa shown in drawing 3 is expressed on behalf of the light from the point light source of one selected element lens.
[0017] Here, the relation between the protection-from-light section configuration of a gobo 8 and element lens arrangement of the fly eye lens 7 is the same as what was shown in drawing 2 , and actually, the outside of the circle C1 in drawing 2 is also made into the protection-from-light section, and it vapor-deposits and makes a metal layer etc. for it on transparency plates, such as a quartz plate, also including cross-joint-like protection-from-light section 8A. Moreover, the injection side (or field of a gobo 8) of the fly eye lens 7 has relation of the optical Fourier transform to the pattern side of Reticle R. Therefore, by the condenser lens 11, the light from the point light source made from one element lens of the fly eye lens 7 serves as the parallel flux of light of an angle of incidence theta, and carries out oblique illumination of the reticle R. At this time, the eccentricity (distance from an optical axis AX) on one Fourier transform side of the point light source is in the sine (sin theta) and proportionality of the incident angle theta. As for this angle of incidence theta, an optimum dose value exists according to the pitch of the periodic pattern on Reticle R. Since it is indicated by previous JP,4-225514,A etc. about the decision approach of eccentricity yalpha to a pattern periodic to each of X and the direction of Y, and xbeta, the explanation is omitted here.
[0018] the zero-order diffracted light D0 among each diffracted light generated from the periodic pattern of the specific pitch on Reticle R by the exposure of the illumination light ILb The one primary diffracted light D1 a both-sides tele cent -- Wafer W is reached after being symmetrically distributed within the pupil EP of the rucksack projection optics PL. Therefore, the periodic pattern of the specific pitch on Reticle R is the one primary diffracted light D1. Zero-order diffracted light D0 Image formation is carried out on Wafer W as a light-and-darkness image made by interference. Since the resist layer is applied to the front face of Wafer W, the open time amount of shutter 19A is controlled, and if the optimal exposure quantity of light corresponding to the resist is given, the contraction image of the periodic pattern of Reticle R will be formed in a resist layer.
[0019] The wafer W is laid on the stage WST which carries out two-dimensional migration in a field perpendicular to an optical axis AX, and Stage WST is driven by drive unit 18B, such as a motor, based on the measurement result of the coordinate location by laser interferometer 18A. A control unit 20 controls the wafer stage WST, drive unit 19for shutters B, and drive unit 10A for turrets in generalization. The automatic control according to the library-name of Reticle R to drive unit 10A for turrets or the manual control by the directions from an operator is especially possible.
[0020] Drawing 4 is the top view showing the concrete configuration of the gobo 8 by the 1st example, and drawing 5 shows typically the periodic pattern arrangement on the reticle R when seeing by the same system of coordinates as the system of coordinates XY in drawing 4 . Although it is few if many the periodic vertical patterns Pv (a pitch is the direction of X) parallel to Directions X and Y and the horizontal patterns Ph (a pitch is the direction of Y) of appearance each side of a reticle exist on Reticle R and it carries out comparatively compared with them as shown in drawing 5 , the periodic slanting patterns Ta and Tb which carried out 45-degree (or 135 degrees) rotation to each of X and the direction of Y also exist. It is that the configuration of such a pattern is common not only in this example but the reticle as the circuit original edition for semiconductor devices, and there are many rates of the vertical pattern Pv and the horizontal pattern Ph, and few things of the rate of the slanting patterns Ta and Tb are common.
[0021] If the illumination light from the illumination-light study system which applied the gobo 8 shown in drawing 4 is irradiated to the reticle R which has these patterns The resolution and the depth of focus at the time of projection with the vertical pattern Pv on Reticle R and the horizontal pattern Ph improve as usual by making

into the surface light source each of four flabellate form area pellucida 81a, 81b, 81c, and 81d divided by width-of-face 2a and cross-joint-like protection-from-light section 8A of die-length 2b. Here, a gobo 8 has zona-orbicularis protection-from-light section 8B of the outer-diameter value r0 and a bore r in the outermost periphery, and die-length b from a zero (point along which an optical axis AX passes) to the tip of cross-joint-like protection-from-light section 8A is set as the relation of r>b. in addition, the bore edge of zona-orbicularis protection-from-light section 8B -- the circle C1 in drawing 2 -- corresponding -- outer-diameter value r0 of zona-orbicularis protection-from-light section 8B if it shall correspond to the effectual overall diameter (namely, maximum numerical-aperture N.A.) of the pupil EP of projection optics PL -- the bore value r and the outer-diameter value r0 of zona-orbicularis protection-from-light section 8B a ratio -- r/r0 It is exactly the sigma value of a coherence factor.

[0022] Furthermore, in the gobo 8 of drawing 4 , the area pellucida 81e, 81f, 81g, and 81h effective in the image formation of the slanting patterns Ta and Tb is formed in each point of X of cross-joint-like protection-from-light section 8A, and the direction of Y. In this conventional kind of lighting, those four area pellucida 81e, 81f, 81g, and 81h was altogether made into the protection-from-light section. When a light source image (surface light source) is made to each of these four area pellucida 81e-81h, the side effect that some the resolution and the depth of focuses at the time of projection of the vertical pattern Pv or the horizontal pattern Ph are degraded occurs. However, to the vertical pattern Pv and the horizontal pattern Ph, compared with each effective flabellate form area pellucida [81a-81d] area (or quantity of light), since each area (or quantity of light) of four area pellucida 81e-81h is small enough, it does not spoil greatly the projection engine performance about the vertical pattern Pv or the horizontal pattern Ph.

[0023] It is set to relation [of each values r (sigma), a, and b of a gobo 8], 0.1 r/sigma<=a <= 0.4 r/sigma, and 0.4 r/sigma<=b <= 0.8 r/sigma extent here. A value a The effectiveness as the deformation light source will disappear and not usually different from lighting (a mere round shape or the polygon surface light source centering on an optical axis AX) at all, if it becomes smaller than 0.1 r/sigma (namely, 0.1r0). Furthermore, a value a If it becomes larger than 0.4 r/sigma (namely, 0.4r0), since it will be made in the place which the center-of-gravity point on each four flabellate form area pellucida [81a-81d] area separated greatly from the zero of a gobo 8, Although optimization of the tilt angle of the illumination light is achieved to that to which the pitch became more detailed among the patterns Pv and Ph on Reticle R, optimization is not achieved to the pattern with which the pitch became coarse, but the expansion effectiveness of the depth of focus consists is hard to be acquired of it.

[0024] Moreover, since the unsuitable surface light source, i.e., area pellucida [81e-81h] area, will increase to resolving of the vertical pattern Pv and the horizontal pattern Ph if smaller also about a value b than 0.4 r/sigma, the depth of focus at the time of projection of the patterns Pv and Ph in every direction will decrease remarkably. Conversely, a value b If it becomes larger than 0.8 r/sigma, the improvement effect of the resolution at the time of projection of the slanting patterns Ta and Tb or the depth of focus will diminish.

[0025] Moreover, in the configuration of the gobo 8 shown in drawing 4 , though small, the surface light source section effective in the image formation of the slanting patterns Ta and Tb is included, and the great portion of central cross-joint-like protection-from-light section 8A is also shading the unsuitable surface light source section also not only to the vertical pattern Pv and the horizontal pattern Ph but to the slanting patterns Ta and Tb. for this reason, also in the image formation of the slanting patterns Ta and Tb, rather than the conventional usual lighting (it centers on an optical axis AX -- being mere -- circular or the polygon surface light source), it can be markedly alike and high resolution and the high depth of focus can be obtained.

[0026] Now, drawing 6 shows the configuration by the 2nd example of a gobo 8, and has attached the same sign to the same part as the configuration of the gobo 8 of drawing 4 . Although this example is fundamentally the same as the gobo of drawing 4 , it differs in that the circular protection-from-light section of a radius rc (rc >a) was prepared in the core of central cross-joint-like protection-from-light section 8A'. Thus, if the core of the surface light source is covered in the circular protection-from-light section, about the image formation of the vertical pattern Pv and the horizontal pattern Ph, it will become less than the case where each area of the effective light source section 81a-81d, i.e., four flabellate form area pellucida, is drawing 4 , and the rate of each area of the effective light source section 81e-81h, i.e., four area pellucida, will increase about the image formation of the slanting patterns Ta and Tb relatively especially. For this reason, the resolution and the depth of focus at the time of the image formation of the slanting patterns Ta and Tb are further improvable from the

case of drawing 4 .
[0027] Moreover, the part newly shaded with the gobo 8 of drawing 6 is a location near an optical axis AX in comparison, and the effectiveness of improving the depth of focus at the time of the image formation of the vertical pattern Pv of a pitch [being a little coarse (the line breadth for example, on a wafer being 0.5 micrometers or more)] and the horizontal pattern Ph does not not much have the effectiveness of improving resolution and the depth of focus to the length of a more detailed pitch of a certain thing, and the horizontal patterns Pv and Ph. Therefore, though it is few, when the L&S pattern on the reticle R which should carry out projection exposure is restricted to the thing of a comparatively detailed pitch, and the comparable slanting pattern of a pitch is also contained at a moderate rate, the synthetic image formation engine performance of the length and the horizontal patterns Pv and Ph using the gobo 8 of drawing 6 does not deteriorate [the time of using the gobo 8 of drawing 4 / especially].
[0028] It is set to the radius r2 of the circular protection-from-light section of the center of the gobo 8 of drawing 6 , and 0.3 r/sigma<=r 2 <=0.4 r/sigma extent here, and the conditions of a<r2<b are also considered strictly. If the value of a radius r2 becomes small and it becomes a>=r2 after all here, in order not to be different from the configuration of the gobo 8 of drawing 4 at all, the depth of focus expansion operation at the time of the image formation of the slanting patterns Ta and Tb will decrease a little. Conversely, if the value of a radius r2 is enlarged, since the surface light source configuration approaches the zona orbicularis, the depth of focus expansion operation at the time of the image formation of length and the horizontal patterns Pv and Ph will decrease.
[0029] Although drawing 7 shows the configuration by the 3rd example of a gobo 8 and is fundamentally the same as the configuration of the gobo 8 of drawing 4 , it is the inside of zona-orbicularis-like protection-from-light section 8B of a periphery, and differs in that the very small protection-from-light sections 8C and 8D which have the corner of 90 degrees in a part of each four flabellate form transparency sections 81a-81d were formed. These very small protection-from-light sections 8C and 8D had the edge parallel to each of the X-axis and a Y-axis, only distance dy has separated them from the X-axis in the direction of Y, and only distance dx has separated the Y-axis and the parallel edge from the Y-axis in the direction of X. Those very small protection-from-light sections 8C and 8D are formed in the furthest part from each of the X-axis and a Y-axis in flabellate form protection-from-light sections [81a-81d] each, and the illumination-light bundle from the part of these protection-from-light sections 8C and 8D has the orientation property optimized to the thing which has the smallest pitch, or the slanting pattern of a detailed pitch as the vertical pattern Pv and a horizontal pattern Ph. For this reason, a depth of focus expansion operation is acquired at the time of the image formation of length with the such smallest pitch, a horizontal pattern, or a detailed slanting pattern. However, an illumination-light bundle will act in the direction which decreases the depth of focus rather at the time of the image formation of a L&S pattern whenever [of whenever / middle / (for example, line breadth of 0.4-0.5 micrometers)] detailed from the part of the protection-from-light sections 8C and 8D.
[0030] Therefore, it can be said that the gobo 8 of drawing 7 is suitable for carrying out projection exposure of the reticle R containing a L&S pattern whenever [of whenever / coarser than it middle] detailed although a detailed pattern in every direction is not included in minimum pitch extent in which theory top image formation is possible with a deformation light source method here. In addition, the distance dx and dy of the edge of the very small protection-from-light sections 8C and 8D is set to dx<r and dy<r here, and if each pitch of the vertical pattern on a reticle, a horizontal pattern, and a slanting pattern is almost comparable, they will be further set to dx=dy, so that clearly from drawing 7 . And the location of each flabellate form area pellucida [in the gobo 8 of drawing 7 / 81a-81d] area center-of-gravity point (quantity of light center-of-gravity point) is not changing so much with a center-of-gravity point location in case the very small protection-from-light sections 8C and 8D do not exist. Moreover, if X of each edge of the very small protection-from-light sections 8C and 8D and distance dx and dy from a Y-axis are made small, each flabellate form area pellucida 81a-81d approaches the rectangle (or square).
[0031] Drawing 8 shows the configuration of the gobo 8 at the time of doubling each edge of cross-joint-like protection-from-light section 8A, zona-orbicularis-like protection-from-light section 8B, and the very small protection-from-light sections 8C and 8D with the cross-section configuration (here, it considering as a square) of the element lens of the fly eye lens 7 while making comparatively small X of each edge of the very small protection-from-light sections 8C and 8D, and distance dx and dy from a Y-axis. In addition, also previous

drawing 4 R> 4, drawing 6 , and in each gobo of 7, the protection-from-light section edge of doubling with the cross-section configuration of an element lens is desirable. four area pellucida 81e-81h which forms the effective light source part at the time of the image formation of the slanting patterns Ta and Tb in drawing 8 -- respectively -- being alike -- two element lenses are located on both sides of the X-axis and a Y-axis. Moreover, the mesial magnitude a of the width of face of cross-joint-like protection-from-light section 8A is set to the dimension for one piece of an element lens, and die-length b is set to the dimension for five pieces. And what removed one element lens of the outermost angle from the set of 4x4 element lenses is located in flabellate form area pellucida [81a-81d] each. In addition, the part equivalent to the very small protection-from-light sections 8C and 8D has covered two element lenses, respectively. moreover, in the case of the gobo 8 of this drawing, four flabellate form area pellucida 81a-81d and area pellucida 81e-81h are not connected like each old example, but are mutually-independent -- it is a thing the bottom. The protection-from-light section of the same square (or rectangle) may be added to a core with the magnitude of the aggregate of 4x4 element lenses so that one element lens located in each innermost angle (corner nearest to a zero) of four more flabellate form area pellucida 81a-81d may be covered. By addition of such the square protection-from-light section, the same operation as the gobo 8 of the 2nd example shown in previous drawing 6 and effectiveness can be acquired. In this case, the distance from the X-axis of the edge of each side of the main square protection-from-light section and a Y-axis is set to the range comparable as the radius C of the circular protection-from-light section of drawing 6 .

[0032] The element lens group of the fly eye lens 7 located in flabellate form area pellucida [which was furthermore shown in drawing 8 / 81a-81d] each is a symmetric design to the X-axis and a Y-axis altogether. By taking such symmetry arrangement, the TERESEN error (strike slip of an image when a wafer side shifts from a best focus side slightly) of the projection image of the L&S pattern on a reticle becomes that there is nothing.

[0033] When drawing 4 and the gobo 8 of drawing 6 -8 are used with reference to drawing 9 here, distribution within the pupil surface EP of the image formation flux of light which generated from Reticle R and carried out incidence to projection optics PL is explained. The quantity of light center-of-gravity points 80A, 80B, 80C, and 80D of the four flabellate form surface light source sections which drawing 9 is what was expressed corresponding to drawing 2 , and were optimized to the length of a predetermined pitch, and the horizontal patterns Pv and Ph, Typical one center-of-gravity point 80E of the four quantity of light center-of-gravity points optimized to the slanting pattern Ta of the same pitch as the length and the horizontal patterns Pv and Ph is shown on a pupil surface EP. Each of four center-of-gravity points 80A-80D is mostly in agreement with each area-center of gravity of four flabellate form area pellucida 81a-81d in each example, and center-of-gravity point 80E is mostly in agreement with the area center-of-gravity point of area-pellucida 81e. First, since four center-of-gravity points 80A-80D are optimized to the pitch of the target length and a horizontal pattern For example, by the exposure of the illumination-light line which passes along center-of-gravity point 80A among the image formation flux of lights from Reticle R, the zero-order light generated from length and a horizontal pattern passes along center-of-gravity point 80A, and one side of the primary [**] diffracted light superimposes and passes along each of the X-axis and a Y-axis, and the center-of-gravity points 80B and 80D of being located symmetrically.

[0034] **1 order diffracted light**Dx1 (center of gravity of a diffracted light bundle) generate from the vertical pattern Pv by the illumination light line by which orientation be carried out on the other hand so that it might pass along center of gravity point 80E -- center of gravity point 80E -- a passage -- a line top parallel to the X-axis -- be distribute -- although -- the location -- drawing 9 -- like -- a pupil surface EP -- since it become the outside of an overall diameter, the image formation of the vertical pattern Pv be affect. However, the one primary diffracted light generated from the horizontal pattern Ph - Since Dy1 (center of gravity of a diffracted-light bundle) is distributed on the Y-axis in Pupil EP, it affects the image formation of the horizontal pattern Ph. This primary diffracted light - Dy1 Since the ideal distribution locations by the deformation illumination of the horizontal pattern Ph differ, they are a light which is not not much desirable for the image formation of the horizontal pattern Ph. however, the amount of illumination light which makes center-of-gravity point 80E is decided by area-pellucida 81e of a small area, and is alike and small compared with the amount of illumination light of other four center-of-gravity points 80A-80D. the ratio -- for example, the case of drawing 8 -- the ratio of the number of the element lenses of the fly eye lens 7 -- being decided -- therefore, 1 order diffracted-light-

Dy1 which is not desirable It is markedly alike, and the quantity of light itself is small and it does not degrade practically the image formation engine performance of the horizontal pattern Ph greatly.
[0035] Next, distribution of the image formation flux of light from the slanting pattern Ta (45 degrees) is considered. Here, the diffracted light generated from the slanting pattern Ta by the exposure of the illumination light (transparency section of flabellate form area-pellucida 81b) by which orientation was carried out so that it might represent and zero-order light might pass along center-of-gravity point 80B is described. Supposing the pitch of the slanting pattern Ta be comparable as the pitch of length and the horizontal patterns Pv and Ph, it be the primary diffracted light from the slanting pattern Ta. - Dt1 (center of gravity of the diffraction flux of light) be locate on the line (135 degrees) which be on the circle of radius 2yalpha (or 2xbeta) center on center of gravity point 80B, and connect the center of gravity points 80B and 80B through an optical axis AX. This primary diffracted light - Dt1 Since it does not have the zero-order flux of light which passes along center-of-gravity point 80B, and symmetrical relation about the 45-degree line which connects two center-of-gravity points 80A and 80C, to the image formation of the slanting pattern Ta, it is the light which is not desirable.
[0036] However, since area-pellucida 81e is prepared in the gobo 8 so that the zero-order light from the slanting pattern Ta may be located in center-of-gravity point 80E the circle top of centering on center-of-gravity point 80E radius [' / which was generated from the slanting pattern Ta by the illumination light from area-pellucida 81e / primary diffracted-light-Dt1] 2yalpha (or 2xbeta) -- and it is located on the 135-degree line (parallel to the line which connects the center-of-gravity points 80B and 80D) which passes along center-of-gravity point 80E. The physical relationship of the center-of-gravity point 80E and primary diffracted-light-Dt1' is the symmetry mostly to the 45-degree line (medial axis in the Fourier transform image of the slanting pattern Ta) which connects the center-of-gravity points 80A and 80C. Therefore, the illumination light from area-pellucida 81e becomes an effective component to the image formation of the slanting pattern Ta, and works in the direction which improves the resolution and the depth of focus of a slanting pattern. In addition, in the case of drawing 9 , primary diffracted-light-Dt1' from the slanting pattern Ta which makes center-of-gravity point 80E zero-order light is located on about X shafts, and the location is approaching the center-of-gravity point (referred to as 80H) of the illumination light from 81h of other area pellucida for the slanting patterns of a gobo 8 further. Thus, that center-of-gravity point 80H of 81h of area pellucida are located in the location of primary diffracted-light-Dt1' means being illuminated by two illumination-light bundles toward which the slanting pattern Ta inclined symmetrically in the pitch direction.
[0037] What is necessary is just to arrange ideally each quantity of light center-of-gravity point of the surface light source section (area pellucida 81e-81h) added to slanting patterns from a zero on the X-axis and a Y-axis to the place of the distance of root (xbeta2+yalpha2), if [thing / above / each pitch of length / which should carry out projection exposure /, horizontal pattern Pv and Ph, and slanting patterns Ta and Tb] comparable on the reticle whose number is one. This relation is ideal conditions, and actually, even if shifted from that relation a little (for example, 20% - about 30%), as it is, the effectiveness of this invention is acquired.
[0038] Drawing 10 changes the part of the fly eye lens 7 which showed the partial configuration of the illumination-light study system by the 4th example of this invention, and was shown in drawing 3 here into the fly eye lens system of 2 reams which are indicated by JP,3-78607,B. Incidence of the illumination light ILa which passed along the collimator lens 4 and prism 30 in drawing 3 is carried out to the 1st step of fly eye lens 7E like drawing 10 . This fly eye lens 7E should bundle every four element lenses in X and the direction of Y. The illumination light from each of the point light source image which carried out image formation to the injection edge of each element lens of fly eye lens 7E overlaps and irradiates the whole surface of the 2nd step of plane of incidence of fly eye lens 7F through a lens system 25. The 2nd step of fly eye lens 7F are what bundled the element lens in 6x6 arrays, and image formation of the three-dimension light source image (point light source) is carried out all over the space distant from the injection side of each element lens about several mm. Since 4x4 point light source images formed in the injection side of the 1st step of fly eye lens 7E are formed in each element lens's of fly eye lens 7F injection [the 2nd step of] side in the case of this 2 ream fly eye lens system, a three-dimension light source image serves as the surface light source to which the 16x36 point light sources gathered two-dimensional.
[0039] Now, in the case of this example, drawing 4 and the gobo 8 shown in drawing 6 -8 are fly eye lens 7F injection [the 2nd step of] sides, and is arranged in the field in the space in which a three-dimension light source image is formed. Drawing 11 shows the arrangement relation of the three-dimension light source image

and each edge of the protection-from-light sections 8A (8A') and 8B of a gobo 8 which were formed in the injection side of fly eye lens 7F. As shown in drawing 11 R> 1, the 4x4 point light sources SP have aligned in X and the direction of Y in the ** pitch mostly at the one element lens's injection side of fly eye lens 7F. At this time, all of the appearance edge of cross-joint-like protection-from-light section 8A (8A') or the edge corresponding to the bore circle C1 of surrounding zona-orbicularis-like protection-from-light section 8B are crooked according to the pitch of the point light source which forms a three-dimension light source image. That is, although the edge of each protection-from-light section needed to be specified according to the cross-section configuration of the element lens of a fly eye lens as shown in drawing 8 at the time of a single fly eye lens system, there is such no need by 2 ream (tandem) fly eye lens system. and since the number of the point light sources which form a three-dimension light source image is boiled markedly and is increasing rather than the case of a single fly eye lens system, the average illumination distribution as the surface light source becomes very flat.

[0040] drawing 12 shows the configuration of the illumination system brought near by the 5th example of this invention, and it constitutes the surface light source for patterns in every direction which four quadrants are alike, respectively and is located by XY system of coordinates on the Fourier transform side within an illumination system from fly eye lenses 70A, 70B, 70C, and 70D which became independent, respectively as indicated by JP,4-225514,A here. And the square drill prism 26 divides the illumination-light bundle of the zona-orbicularis-like distribution from a collimator lens 4 into the four flux of lights, and incidence of each is carried out to four fly eye lenses 70A-70D. Moreover, the surface light source for slanting patterns is constituted from points 70E, 70F, 70G, and 70H of four optical fibers 90, the four other end (incidence edge) side of an optical fiber 90 is bundled by one, and a part of illumination light which branched after shutter 19A is condensed by the incidence edge.

[0041] Since the system which makes the surface light source for slanting patterns from this example has been independent of the system which makes the surface light source for patterns in every direction, when the slanting pattern does not exist at all on the reticle used as the candidate for projection, into the optical path of incidence one end of an optical fiber 90, another shutter and an extinction filter (ND filter) can be inserted, and luminescence of Points 70E-70H can be forbidden, or a quantity of light fall can be carried out sharply. Furthermore, since the luminescence reinforcement of Points 70E-70H can be changed by adjustment of the rate of extinction of the ND filter etc., the optimal quantity of light can be given according to the rate that a slanting pattern closes among the L&S patterns on Reticle R. therefore, if the operator makes information on the slanting pattern on Reticle R with which is resembled comparatively and it is related the configuration inputted into the main control unit 20 in drawing 3 , the luminescence reinforcement of four points 70E-70H can also be automatically adjusted to an optimum value (zero are also included) according to the table which was able to be defined beforehand. Moreover, since four fly eye lenses 70A-70D and four points 70E-70H are independently formed as shown in drawing 12 , according to the pitch of the pattern of L&S on Reticle R, each fly eye lens or a point may be made two-dimensional or movable to one dimension in XY side. In that case, the quantity of light center-of-gravity point of the surface light source by the side of each injection of the fly eye lenses 70A-70D the pitch of an in every direction pattern and slanting pattern is comparable, and is [eye lenses] four When taking the arrangement corresponding to four corners of the square centering on an optical axis AX in XY side It is good to make it movable by relation to which the eccentricity from the optical axis AX of the quantity of light center-of-gravity point of four fly eye lenses 70A-70D and the eccentricity from the optical axis of the quantity of light center-of-gravity point of Points 70E-70H become almost equal.

[0042] In addition, each of four fly eye lenses 70A-70D is good as a tandem fly eye lens system as well as drawing 10 , and prepares a diaphragm (gobo) in each injection side of each fly eye lenses 70A-70D according to an individual, and it interlocks and you may make it change each magnitude of the four surface light sources individually in the configuration of drawing 12 . By the way, in drawing 12 , although the gobo etc. is not specially prepared between each of the fly eye lenses 70A-70D, when many [so / that the stray light passing through the space between each fly eye lens cannot be disregarded], it is desirable to prepare an easy gobo (the shape of a cross joint). Therefore, if the stray light component is fully small, it is not necessary to prepare a gobo specially. This is similarly applicable to previous drawing 4 and the gobo 8 shown in drawing 6 -8, and means that it is necessary to use neither cross-joint-like protection-from-light section 8A and 8A' nor zona-orbicularis-like protection-from-light section 8B as a perfect protection-from-light layer. For example, each

protection-from-light section on a gobo 8 may consist of dielectric thin films which have 90% or more of rate of extinction in the wavelength (i line 365nm and KrF excimer laser 248nm) of the illumination light for exposure.

[0043] Now, the example of the drawing configuration of the conventional deformation light source announced until now for explanation of the simulation of the following [here] is shown in drawing 13 and 14. Drawing 13 is the center position (xbeta, yalpha) optimized by the vertical pattern Pv which has a specific pitch, and the horizontal pattern Ph, and an example of the gobo for the circular 4 light sources which has a suitable radius (it is 0.1-0.3 at a sigma value). Drawing 14 is the example of the larger gobo for the flabellate form 4 light sources than the radius r in which it considers as square opening instead of circular opening of drawing 13 , respectively, and a part of these four surrounding square openings are equivalent to the sigma value of an illumination-light study system.

[0044] The simulation result of the depth of focus DOF [mum] to Rhine of the L&S pattern image obtained as an example at the time of projection of the in-every-direction L&S pattern using the light source configuration shown in drawing 14 and a slanting (45-degree or direction of 135 degree) L&S pattern or the line breadth size [mum] of a tooth space is shown in drawing 15 . The conditions of simulation wavelength lambda here 0.365 of i line [mum], Numerical aperture by the side of the wafer of projection optics PL N.A. 0.50 (a reticle side 0.1), The bore r of zona-orbicularis-like protection-from-light section 8B of a gobo 8 is made into a sigma value (r/r0). 0.8 (the sigma value of the usual circular surface light source is also set to 0.8), Mesial magnitude a of the width of face of the cross-joint-like protection-from-light section was made into 0.28, i.e., a=0.28r/sigma=0.35r, by numerical-aperture conversion (usually with [in lighting / a= 0] no cross-joint-like protection-from-light section). The value of the depth of focus (DOF) was made into the constant value decided by 1.2 micrometers in thickness of the resist which should be carried out pattern NINGU, and the refractive index 1.7 of those, and the value which deducted 1.2 / 1.7**0.706 [mum] here from the range (full) where the contrast of 1:1 lines and a tooth-space (last shipment) pattern image becomes 60% or more. The property DV 1 of the simulation result expressed with the two-dot chain line in drawing 15 shows the depth of focus property over the length when using the conventional gobo of drawing 14 , and a horizontal L&S pattern, and the simulation property DO 1 of a broken line shows the depth of focus property over the slanting (45-degree, 135 degrees) L&S pattern when using the gobo of drawing 14 similarly. In the conventional deformation light source configuration like drawing 14 R> 4, a result which is more slightly [than the depth of focus property DC over the slanting pattern when using the usual circular surface light source which the depth of focus property DO 1 over a slanting pattern simulated for the comparison] inferior is brought. In addition, in the case of the usual circular light source configuration, it becomes the depth of focus property DC also to any of length, width, and a slanting pattern.

[0045] Drawing 16 shows the simulation result of the depth of focus property when using the gobo 8 by the 1st example (drawing 4) of this invention. At this time, the mesial magnitude a of the width of face of cross-joint-like protection-from-light section 8A in drawing 4 was set to a=0.28r0 =0.35r, and mesial magnitude b of die length was set to b=0.56r0 =0.7r, and it made the exposure wavelength lambda, N.A., and sigma the same as the case of drawing 15 . Although the depth of focus property DV 2 in the L&S pattern of 1:1 in every direction in this condition is more slightly [than the property DV 1 by the conventional deformation light source in drawing 15 (drawing 14)] inferior, on the other hand, it is turning around the depth of focus property DO 2 over a slanting L&S pattern the top [property / DC / when using the usual circular surface light source / depth of focus], and the effectiveness of this invention is checked. Moreover, there are depth of focus properties DV 2 of enough over a pattern in every direction, and the deformation light source does not spoil the capacity which it essentially has. In addition, although the mesial magnitude a of the width of face of the cross-joint-like protection-from-light section and mesial magnitude b of die length were set to a= 0.28r0 (0.28 times of numerical-aperture N.A. of projection optics), and b= 0.56r0 (0.56 times of numerical-aperture N.A.) in this simulation, respectively These values are values a, as it is not limited to it and stated previously. That what is necessary is just 0.4r0.1r0 <=(0.1 and N.A.) a<= 0 (0.4 and N.A.) extent Value b 0.4r0 (0.4 and N.A.)<=b<0.8r0 (0.8 and N.A.) If it is extent, the effectiveness of this invention can be acquired. However, the upper limit of a value b needs to be b<r to the value of a radius r.

[0046] Drawing 17 shows the simulation result of the depth of focus property when using the gobo 8 by the 2nd example (drawing 6) of this invention. At this time, the gobo 8 is what combined the cross-joint-like protection-from-light section and the center circle form protection-from-light section as it was shown in

drawing 6 . Simulation conditions the mesial magnitude a of the width of face of 0.7 and the cross-joint-like protection-from-light section by sigma value (r/r0) conversion for the bore r of 0.50 and zona-orbicularis-like protection-from-light section 8B of the periphery of a gobo 8 0.28r0, [the exposure wavelength lambda] [0.365 micrometers (i line) and wafer side numerical-aperture N.A. of projection optics PL] It is the radius c of 0.56r0 and the center circle form protection-from-light section about the mesial magnitude b of die length 0.46r0 It carried out. like the simulation result of drawing 17 , compared with the depth of focus property DC in the conventional usual circular surface light source (sigma=0.7), the depth of focus property DO 3 of a slanting L&S pattern is boiled markedly, and improves, and the depth of focus property DV 3 over length and a horizontal L&S pattern serves as a value big enough.

[0047] although the value of the radius c of the center circle form protection-from-light section was made into 0.46 r/sigma in simulation here -- the mesial magnitude a and b of the above-mentioned [this] -- similarly it is not necessarily limited to 0.46 r/sigma -- if it is 0.3 r/sigma (0.3 and N.A.) <c< 0.6 r/sigma (0.6 and N.A.) extent, the effectiveness of this invention can fully be acquired. However, if the value of a radius c is too small, since the gobo 8 of drawing 6 will serve as the same configuration as the gobo of drawing 4 , the improvement factor of the depth of focus about a slanting pattern will decrease a little. That is, the property DO 3 in drawing 17 becomes like the property DO 2 in drawing 16 . Moreover, if the value of a radius c is not much large, in the depth of focus property DV 3 over a L&S pattern in every direction, the part to which the depth of focus as which pattern size is regarded near 0.45 micrometer becomes large especially stops existing, and it is not desirable [it] too in order to approach zona-orbicularis lighting (after-mentioned).

[0048] Drawing 18 shows the simulation result when using the gobo 8 by the 3rd example (drawing 7) of this invention. the simulation conditions in this case -- numerical aperture of projection optics N.A. the sigma value (r/r0) which is the maximum radius of 0.50 and the surface light source -- each dimension of 0.8 and cross-joint protection-from-light section 8A, mesial magnitude a, and mesial magnitude b -- respectively -- the distance d to 0.28r0, 0.56r0, and the surrounding minute protection from light 8C and 8D -- 0.64r0 ** -- it carried out. If the simulation result of this drawing 18 is compared with the simulation result shown in above-mentioned drawing 16 , the depth of focus property DO 4 about the slanting pattern when using the gobo 8 of drawing 7 Being improved to the same extent as the depth of focus property DO 3 (drawing 17) when using the depth of focus property DO 2 (drawing 16) when using the gobo 8 of drawing 4 , or the gobo of drawing 6 It turns out especially among L&S patterns in every direction that the depth of focus is improved like the depth of focus property DV 4 also about a pattern whenever [of whenever / middle / of about 0.45-micrometer Rhine width of face] detailed.

[0049] In addition, the value of the edge distance d of the minute protection-from-light sections 8C and 8D in the gobo of drawing 7 is also 0.64r0. It is not necessarily limited and is 0.5r0<d<0.8r0. What is necessary is just the range of extent. However, when distance d is not much small, the resolution to a pattern in every direction will fall, and if not much large, effectiveness will not appear. Then, the center circle form protection-from-light section like drawing 6 which shades near the optical axis of the gobo 8 shown in drawing 7 further, or the square protection-from-light section may be added.

[0050] Drawing 19 shows the same simulation result in zona-orbicularis lighting for a comparison. The conditions at this time set exposure wavelength lambda to 0.365 micrometers, and consider the zona-orbicularis [which made the center circle form section which is equivalent to the radius (sigma=0.35) of that one half among the circular surface light sources of the radius equivalent to 0.7 and N.A. (sigma=0.7) the protection-from-light section]-like surface light source. In the depth of focus property DA over the L&S pattern obtained with such zona-orbicularis lighting, the depth of focus of about about 1.5 micrometers is obtained by width of face about a coarse pattern with Rhine (or tooth space) width of face of 0.42 micrometers or more. In the depth of focus property DC at the time of the conventional circular surface light source, the actual condition is that 1 micrometer cannot be found, either. However, considering the time of exposure of an actual memory pattern, especially, by the exposure process of a metal wiring layer, the big depth of focus is required, for example, the depth of focus of 2 micrometers or more is needed by width of face to a L&S pattern with a line breadth of about 0.45 micrometers at 64MDRAMs. Therefore, it is difficult like drawing 19 to fill this demand with the depth of focus property DA acquired with zona-orbicularis lighting. Moreover, since that especially the depth of focus is needed also at the exposure process of an above-mentioned metal wiring layer is the length and the horizontal L&S pattern which are formed in the level difference (about 1 micrometer) section, a deformation

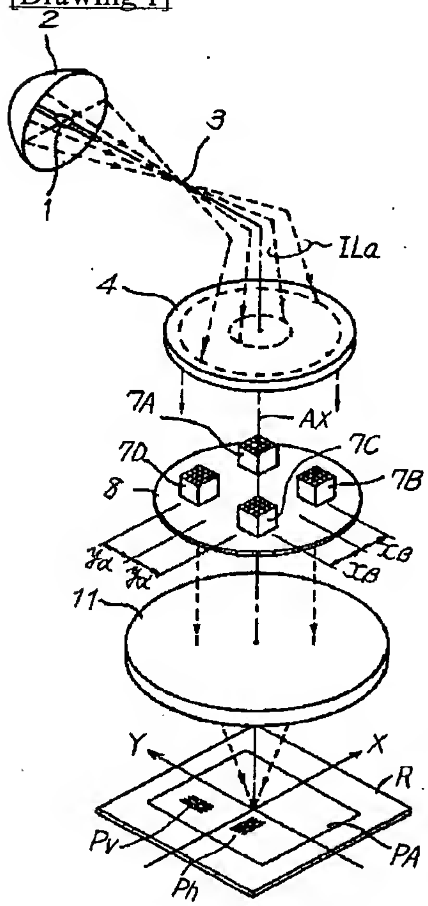
light source configuration like this invention is very effective.
[0051] In addition, although i line shall be used by using the light source as a mercury lamp into an example, this may be other wavelength or may be the light source of laser etc. Moreover, at the conditions of simulation, it is the numerical aperture of projection optics. N.A. It is numerical aperture, although it was referred to as 0.5 and the radius r of the greatest surface light source made with a gobo was set to 0.7 or 0.8 by the sigma value. N.A. and a sigma value are not limited to this. However, about a sigma value, or more 0.7 extent is effective. Moreover, although the outermost form of a light source configuration shall be restricted by the circle (sigma) specified with the bore edge of zona-orbicularis protection-from-light section 8B of a gobo 8, a square, a hexagon, etc. may prescribe the outermost form. Although the protection-from-light section configuration of the gobo 8 in each example was furthermore made into the shape of isomorphism (symmetry form) about the direction of X, and the direction of Y, the configurations may differ in the direction of X, and the direction of Y. That is, the direction of X may differ in the value of the distance c from the core of each edge at the time of preparing the square protection-from-light section in the dimension values a, b, and d of each protection-from-light section, or a core from the direction of Y.
[0052] In an actual illumination system, quantity of light distribution of the injection side of a fly eye lens serves as a discrete set of the point light source discretely according to the array of each element lens of a fly eye lens. At this time, each spacing of the discrete point light source also differs that the cross-section configuration of each element lens is a rectangle in X and the direction of Y. Then, in order to arrange effectual lighting conditions (orientation property of the illumination light to a reticle) in X and the direction of Y, it may be necessary to change positively the value of the dimension values a, b, c, and d of each protection-from-light section in X and the direction of Y. Moreover, in order to centralize the illumination light efficiently to each transparency sections 81a-81d of the gobo 8 used in each example of this invention, and 81e-81h and to reduce quantity of light loss, it is good to establish condensing means (prism, a mirror, fiber, etc.) to centralize the illumination light on those transparency sections, in front of a gobo 8. Although [the gobo 8 of each example] it consists of the transparency section and the protection-from-light section, it is still better also considering all the protection-from-light all [a part or] as the transflective section (permeability is 50% or less desirably). moreover, two or more gobos 8 which had the configuration which can respond to them according to the exposed process since the required depth of focus and the significance of a pattern in every direction and a slanting pattern differed from each other -- the turret 10 of drawing 3 -- preparing -- exchange -- the thing it is supposed that it is usable is desirable. Although the reticle to be used was made into thc usual reticle which consists of the protection-from-light section (chromium layer) and the transparency section in simulation About this invention, it is the so-called halftone phase shift (it has about 1 - 15% of permeability instead of the protection-from-light section). and the halftone transparency section (thin film) from which only pi makes the phase between the light which passes along the transparency section differ is prepared -- if it uses at the time of projection of the reticle of a method, the effectiveness of this invention can be heightened further.
[0053] The gobo 8 shown in each example is acting on an improvement of the depth of focus good at the time of about 0.4-0.5 micrometers by which the line breadth on the wafer of the patterns Pv and Ph in every direction is used at the time of 64 M-DRAM manufacture so that clearly from each above simulation result. And the improvement effect of the depth of focus is acquired by coincidence also about the slanting patterns Ta and Tb. However, if the depth of focus in the same line breadth size is measured by the pattern in every direction and the slanting pattern, to be sure, the depth of focus in the direction of a slanting pattern is not so large. However, the pitch (line breadth size) of the pattern in every direction within the reticle of one sheet is received. When line breadth size is 0.42 micrometers in the property DV 3 over the pattern in every direction in drawing 17 R> 7 when the pitch (line breadth size) of a slanting pattern is coarser about 1.2 to 1.5 times for example, About 2 micrometers of line breadth size 0.63micrometer [in the property DO 3 of as opposed to / that it is the 1.5 times (0.63 micrometers) the line breadth size of a slanting pattern of this / a slanting pattern] depth of focuses will be obtained.
[0054] By the way, when four quantity of light center-of-gravity points (center-of-gravity point of zero-order light) 80A-80D optimized to the pitch of the target pattern in every direction are located in each square angle within the pupil EP of projection optics PL so that clearly from previous drawing 9 , When the pitch of the target slanting pattern is about about 1.4 times of the pitch of a pattern in every direction, quantity of light center-of-gravity point 80E of the illumination light added auxiliary to slanting patterns is ideally in agreement

at the intersection of the segment and Y-axis which connect two center-of-gravity points 80A and 80B.
[0055] Drawing 20 shows signs that each quantity of light center-of-gravity point has been arranged by almost ideal relation, when the pitch relation between a pattern in every direction and a slanting pattern about 1.4 times is above. The zero-order light and the primary diffracted light which are distributed over Pupil EP in this drawing 20 shall have breadth in the surroundings of each center-of-gravity point in predetermined magnitude. Originally, although it is in agreement with the configuration of the surface light sources, such as the area pellucida 81a-81d of a gobo 8, and 81e-81h, the form (field) of the breadth is only circular here, and is expressed.
[0056] 1 order diffracted-light-Dt1 which four zero-order light (center-of-gravity points 80A-80D) generated from a slanting pattern (45 degrees, 135 degrees) was alike, respectively in the case of drawing 20 , and corresponded Pupil EP -- it superimposes and passes along a core mostly. Moreover, primary diffracted-light-Dt1' from the slanting pattern which passes along center-of-gravity point 80E as a zero-order light passes along the congruous locations near [each] the center-of-gravity points 80H and 80F of the source of a fill-in flash for slanting patterns. The primary diffracted light from the horizontal pattern which passes along center-of-gravity point 80E as a zero-order light in coincidence - Dy1 It passes along the congruous locations near center-of-gravity point 80G of the source of a fill-in flash for slanting patterns.
[0057] four 1 order diffracted-light-Dt(s)1 to which the component which reduces the depth of focus expansion effectiveness over the slanting pattern when using the deformation light source among distribution of such a zero-order light and the primary diffracted light appears in the core of Pupil EP it is . Then, such at the time of conditions, an extinction filter (ND filter) is arranged only in the center section of the pupil EP of projection optics, and they are the four primary diffracted lights. - Dt1 It is good to attenuate the quantity of light moderately.
[0058] In addition, the arrangement relation between the circular field which makes four quantity of light center-of-gravity points 80A-80D for the patterns in every direction in drawing 20 , and the small circular field which makes four quantity of light center-of-gravity points 80E-80H for slanting patterns becomes the area-pellucida configuration of the gobo 8 for the deformation light sources and similarity which are prepared in an illumination system as it is. Therefore, as a gobo 8, the thing of the configuration which made transparence four big circular fields in drawing 20 and four small circular fields can be used as it is.
[0059]
[Effect of the Invention] As mentioned above, according to this invention, degradation of the image formation engine performance to the slanting pattern made into the problem by the deformation light source until now, especially a depth of focus improvement factor can be prevented, and the almost same engine performance as the conventional deformation light source can be obtained also about a pattern in every direction.

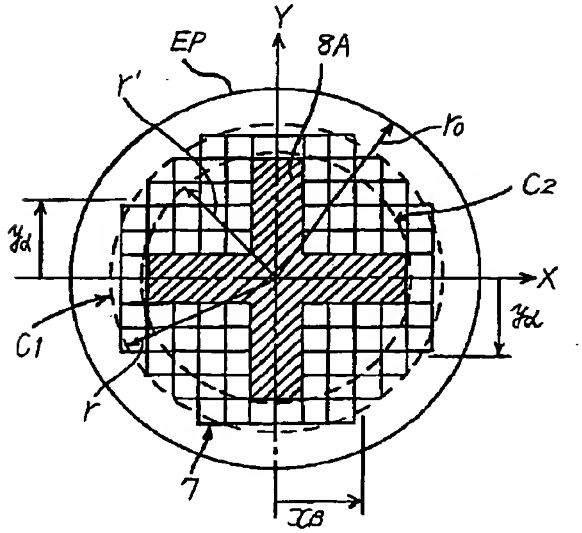
[Translation done.]

DRAWINGS

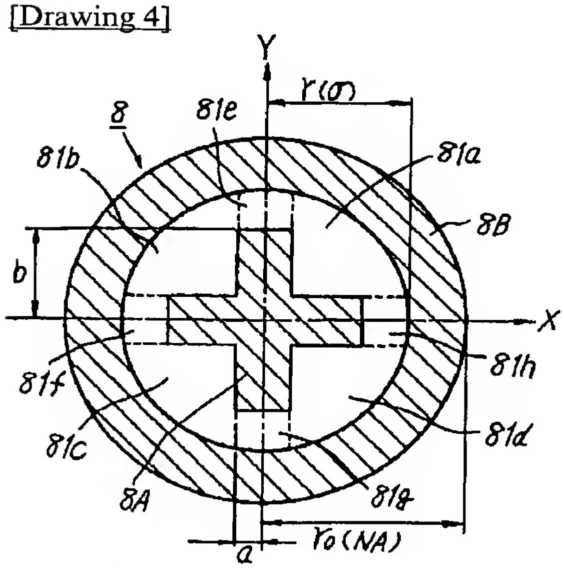
[Drawing 1]



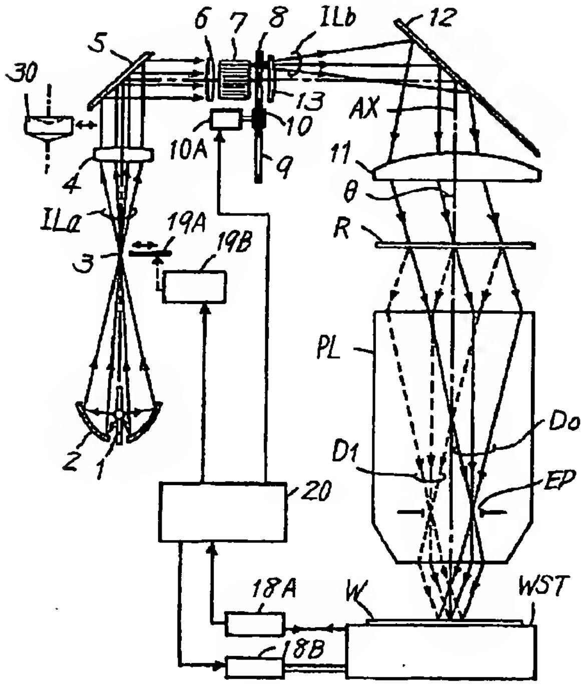
[Drawing 2]



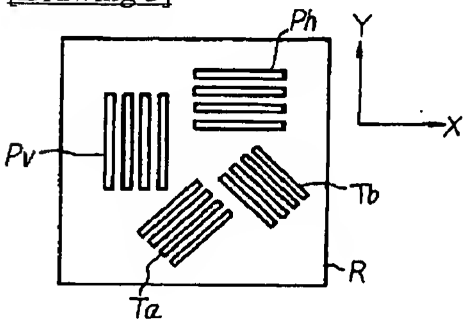
[Drawing 4]



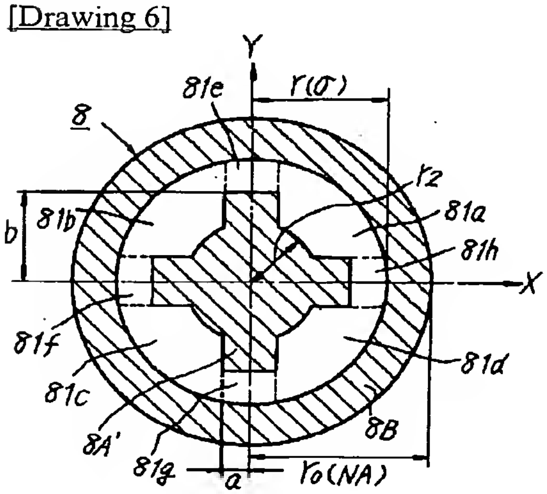
[Drawing 3]



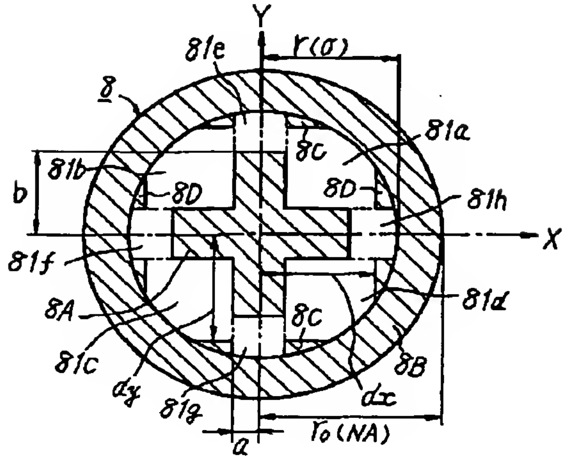
[Drawing 5]



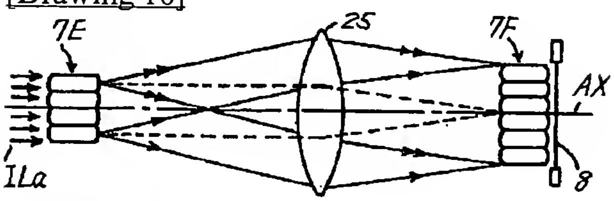
[Drawing 6]



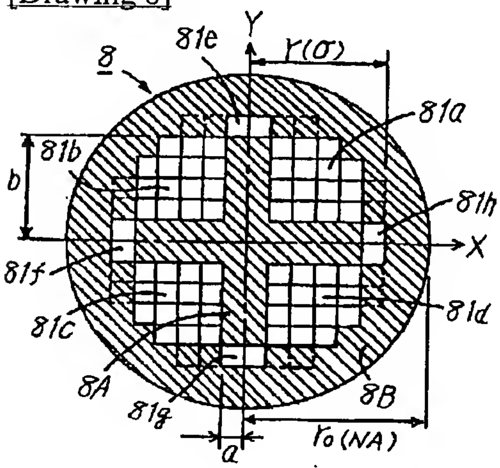
[Drawing 7]



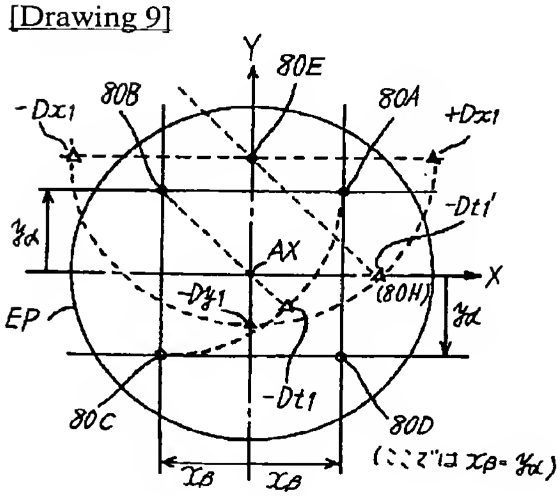
[Drawing 10]



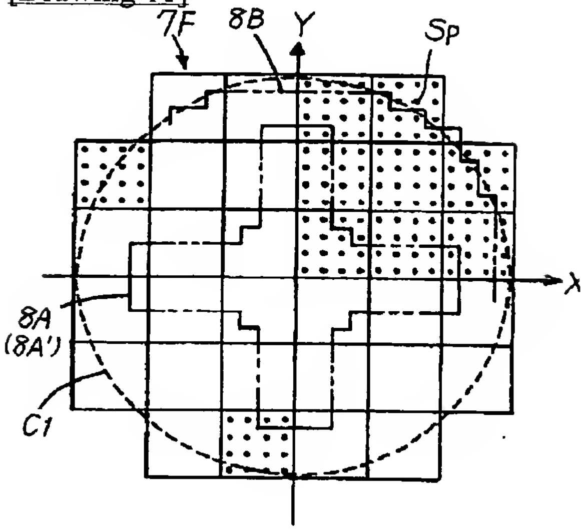
[Drawing 8]



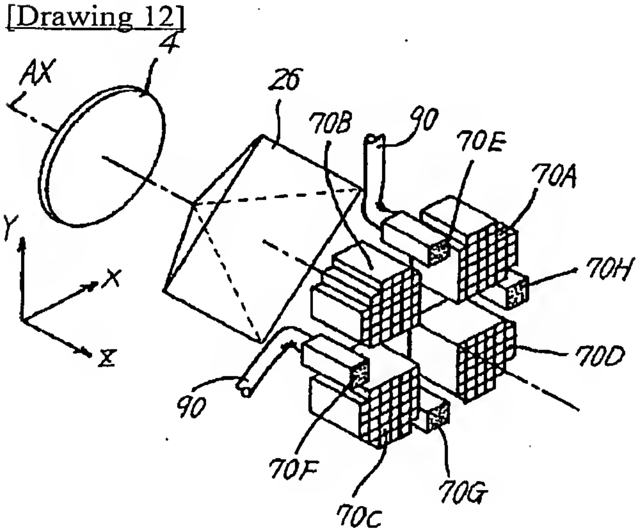
[Drawing 9]



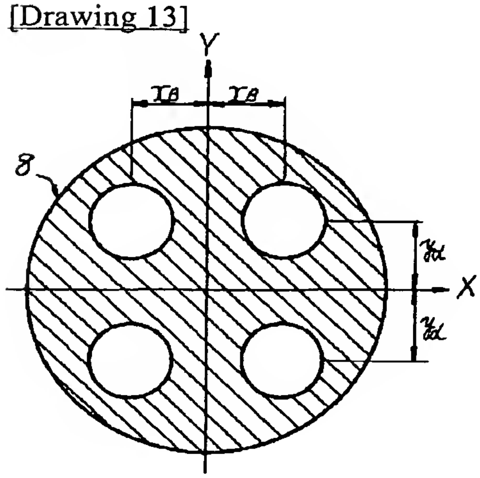
[Drawing 11]



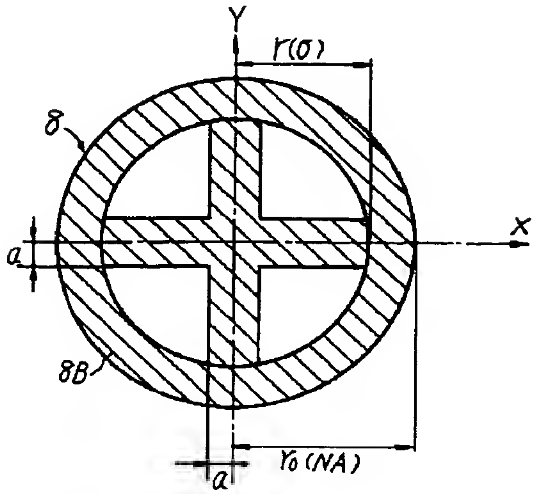
[Drawing 12]



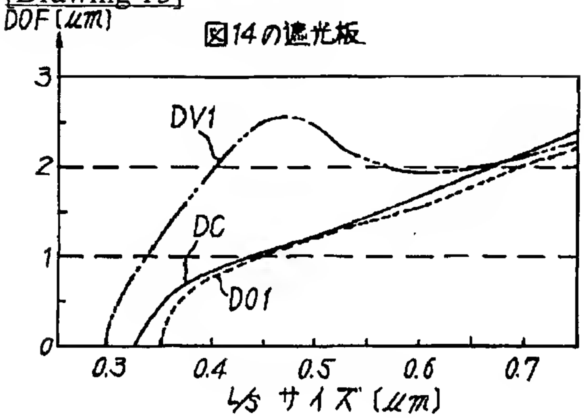
[Drawing 13]



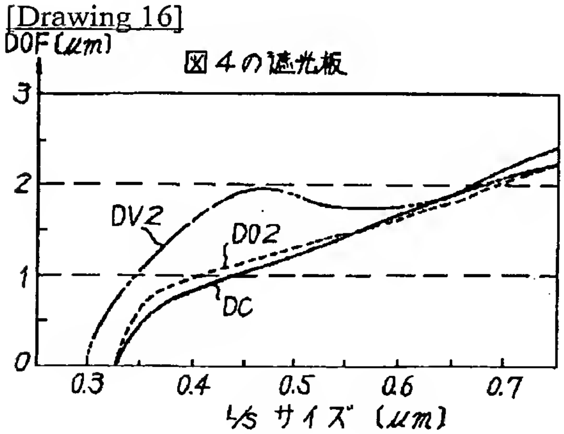
[Drawing 14]



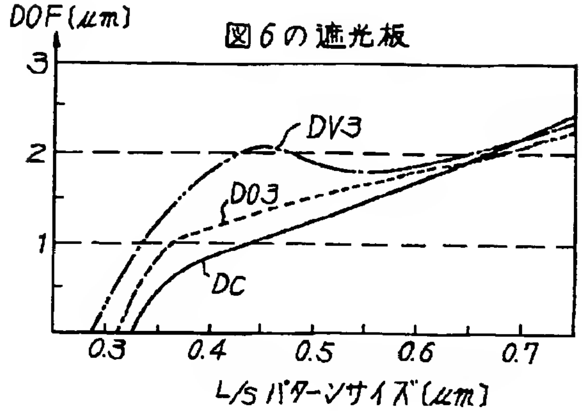
[Drawing 15]



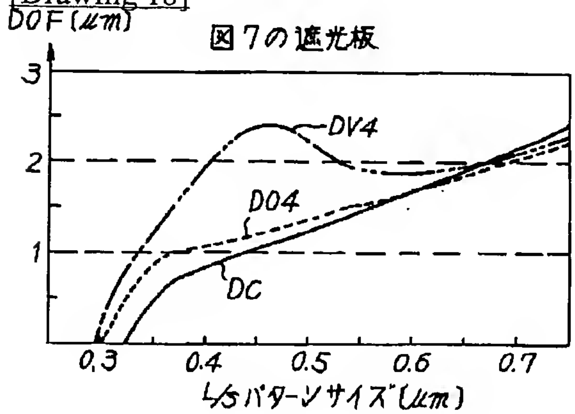
[Drawing 16]



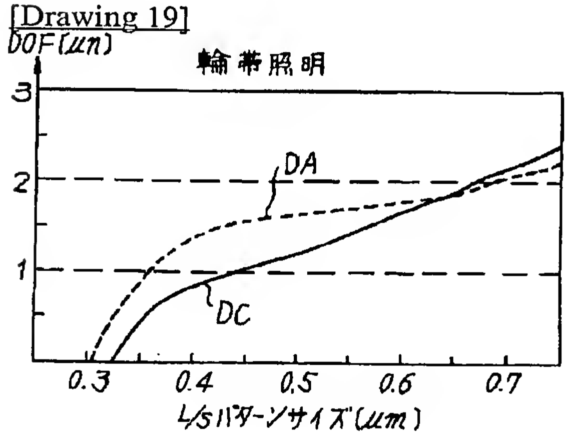
[Drawing 17]



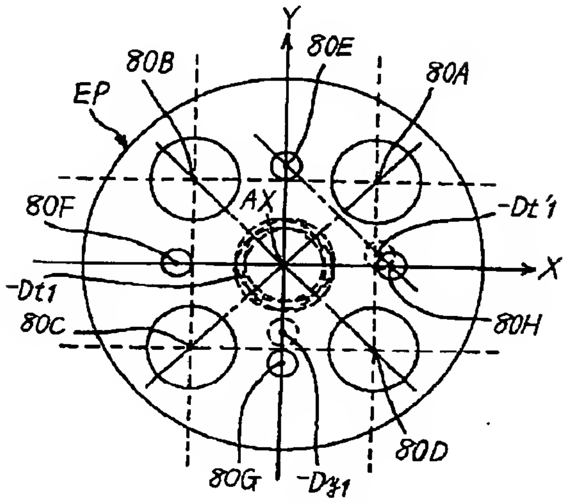
[Drawing 18]



[Drawing 19]



[Drawing 20]



[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law
[Section partition] The 2nd partition of the 7th section
[Publication date] March 23, Heisei 13 (2001. 3.23)

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[Date of Publication] July 15, Heisei 6 (1994. 7.15)
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[Application number] Japanese Patent Application No. 4-342316
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H01L  21/027
G03B  27/32
27/54
G03F   7/20    521
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[FI]

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H01L  21/30    311 S
G03B  27/32        F
27/54         Z
G03F   7/20    521
H01L  21/30    311 L
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[Procedure revision]
[Filing Date] December 20, Heisei 11 (1999. 12.20)
[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] The name of invention
[Method of Amendment] Modification
[Proposed Amendment]
[Title of the Invention] A projection aligner and an approach
[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[Proposed Amendment]
[Claim(s)]
[Claim 1] In the projection aligner equipped with the illumination system which illuminates the mask with which the pattern which should be projected was formed, and the projection optics which projects the image of said pattern on a sensitization substrate,
the illumination-light study system which has the field where said illumination system serves as relation of the Fourier transform optically to the pattern side of said mask inside, and the optical part construction which

distributes the illumination light in the predetermined radius centering on an optical axis on said Fourier transform side or its near side -- a law -- a means -- containing
Said optical distribution setting means is a projection aligner characterized by distributing said illumination light over two or more discrete fields except a core by the inside of the field of the shape of said zona orbicularis while distributing said illumination light in the field of the shape of zona orbicularis of the predetermined width of face centering on said optical axis.
[Claim 2] Said two or more fields are projection aligners according to claim 1 characterized by being divided by the rectangular coordinate system which makes said optical axis a zero and is specified corresponding to said 2-way including the 1st element which has periodicity in the 2-way a 2-way and said pattern cross at right angles mutually, respectively, and the 2nd element which has periodicity in the direction which intersects said 2-way.
[Claim 3] Said two or more fields are projection aligners according to claim 2 characterized by filling 0.1r0<=a<=0.4r0 and 0.4r0<=b<=0.8r0, when width of face of r0 and said cross-joint field is set to 2xa and die length is set to 2xb for the radius of the pupil surface of said projection optics which it was divided in the cross-joint field specified on said rectangular coordinate system centering on said optical axis, and was seen on said Fourier transform side.
[Claim 4] When said core is circular and the radius of the pupil surface of said projection optics seen on said Fourier transform side is set to r0, the radius r2 of said core is a projection aligner given in any 1 term of claims 1-3 characterized by filling 0.3r0 <=r2 <=0.4r0.
[Claim 5] For said optical distribution setting means, in said two or more fields, a part, the rim section is [said a part of rim section] a projection aligner given in any 1 term of claims 1-4 characterized by the distance d with the axis of coordinates of said rectangular coordinate system filling 0.5r0<d<0.8r0, respectively, when the radius of the pupil surface of said projection optics which said illumination light was distributed over except and seen on said Fourier transform side is set to r0.
[Claim 6] In the projection aligner equipped with the projection optics which carries out incidence of the light from the pattern of said mask irradiated by the illumination light from the light source which generates the illumination light which irradiates a mask, the Fourier transform side which serves as relation of the Fourier transform optically to the pattern side of said mask or the illumination-light study system which forms the secondary light source of said light source in the near side, and said illumination-light study system, and projects the image of said pattern on a sensitization substrate,
When there are more rates that are equipped with the following and said 1st element occupies on said mask than the rate that said 2nd element occupies, While setting the 1st surface of light source as each of said Fourier transform side or four fields in which eccentricity is carried out and it is mutually located symmetrically from the optical axis of said illumination-light study system on the near side so that the oblique illumination light corresponding to the periodic direction of said 1st element may be made So that the oblique illumination light corresponding to the periodic direction of said 2nd element may be made Said Fourier transform side, Or the projection aligner which is equipped with the setting member which sets the 2nd surface of light source as each of four fields which carries out eccentricity and is mutually located symmetrically from the optical axis of said illumination-light study system on the near side, and is characterized by making area of said 1st surface of light source larger than the area of said 2nd surface of light source. The 1st element with which said pattern has periodicity in the 2-way which intersects perpendicularly mutually, respectively The 2nd element which has periodicity in the direction which intersects said 2-way
[Claim 7] Said setting member is a projection aligner according to claim 6 characterized by specifying said 1st and 2nd surfaces of light source with the Fourier transform side of said illumination-light study system, the gobo arranged in the near side, or a transflective plate.
[Claim 8] In the projection aligner equipped with the projection optics which projects the pattern containing the 1st element which has periodicity in the 2-way which intersects perpendicularly on a mask, and the 2nd element which has periodicity in the different direction from said 2-way on a sensitization substrate, and the illumination-light study system on which the light from each point within said surface light source is made to superimpose on said mask while carrying out incidence of the light from the light source and forming the surface light source,
The projection aligner characterized by having had the gobo characterized by providing the following and changing said 1st transparency section and said 2nd transparency section in the area according to the significance of said 1st and 2nd elements The 1st transparency section of four quadrants specified with said two

axes of coordinates when setting up two axes of coordinates corresponding to said 2-way by making the core of said surface light source into a zero which is alike, respectively and is mostly formed in the same area The 2nd transparency section mostly formed in each four on said two axes of coordinates in the same area by the equal distance from said zero
[Claim 9] Said gobo is a projection aligner according to claim 8 characterized by being the transflective section except said 1st and 2nd transparency section.
[Claim 10] The projection aligner according to claim 8 or 9 characterized by having further the extinction filter which attenuates the quantity of light of the diffracted light which occurs from said 2nd element and is distributed over the center section of the pupil surface of said projection optics.
[Claim 11] In the projection aligner equipped with the projection optics which projects the pattern of a mask on a sensitization substrate, and the illumination-light study system which carries out incidence of the light from the light source, forms the surface light source in the optical Fourier transform side over said mask, or its near side, and irradiates the light from said surface light source at said mask,
When r and the coherence factor of said surface light source are made into a sigma value for the radius of the circle which defined the rectangular coordinate system XY and was approximated to the appearance of said surface light source by making the core of said surface light source into a zero, Multipliers a and b, respectively as 0.1 r/sigma<=a <=0.4 r/sigma and 0.4 r/sigma<=b <=0.8 r/sigma The projection aligner characterized by preparing the optical intensity-distribution controller material which makes optical reinforcement with the inside of the field of -a<=X<=a, the inside of the field of -b<=Y<=b and -a<=Y<=a, and -b<=X<=b smaller than other fields on said surface light source, or is set to about 0.
[Claim 12] Said optical intensity-distribution controller material is a projection aligner according to claim 11 characterized by making optical reinforcement in the field of X2+Y2 <=c2 smaller than other fields, or being referred to as about 0 on said surface light source when a multiplier c is made into 0.3 r/sigma<=c <=0.6 r/sigma.
[Claim 13] the time of said illumination-light study system being constituted so that image formation of the zero of said surface light source may be carried out to the core of the pupil surface of said projection optics, and setting the radius on said surface light source of the effectual pupil diameter of said projection optics to r0 -- a ratio with the radius r of said surface light source -- the projection aligner according to claim 11 or 12 characterized by making or more into 0.7 said sigma value which is r/r0.
[Claim 14] Said pattern is a projection aligner given in any 1 term of claims 1-13 characterized by being formed in the transparency section and the halftone transparency section.
[Claim 15] In the projection exposure approach which projects the pattern image of said mask on a sensitization substrate through projection optics while irradiating the illumination light through an illumination-light study system at a mask,
The projection exposure approach characterized by distributing said illumination light over two or more discrete fields except a core by the inside of the field of the shape of said zona orbicularis while distributing said illumination light in the field of the shape of zona orbicularis of predetermined width of face centering on an optical axis on the field which serves as relation of the Fourier transform optically to the pattern side of said mask within said illumination-light study system, or its near side.
[Claim 16] In the projection exposure approach which projects the pattern image of said mask on a sensitization substrate through projection optics while irradiating the illumination light through an illumination-light study system at a mask,
The optical Fourier transform side over the pattern side of said mask in said illumination-light study system when irradiating the pattern characterized by providing the following, Or the 1st field set as each of four quadrants specified according to the rectangular coordinate system corresponding to said 2-way which makes an optical axis a zero on the near side, And the projection exposure approach characterized by changing said 1st field and said 2nd field in the area according to the significance of said 1st and 2nd elements while lessening the quantity of light or setting it to about 0 at the equal distance mostly from said zero except the 2nd field set up on the axis of coordinates of said rectangular coordinate system The 1st element which has periodicity in the 2-way which intersects said illumination light perpendicularly on said mask The 2nd element which has periodicity in the different direction from said 2-way
[Claim 17] In the projection exposure approach which projects the pattern image of said mask on a sensitization substrate through projection optics while irradiating the illumination light through an illumination-light study

system at a mask,
The optical Fourier transform side over the pattern side of said mask in said illumination-light study system, Or when r and the coherence factor of said surface light source are made into a sigma value for the radius of the circle which defined the rectangular coordinate system XY and was approximated to the appearance of said surface light source by making into a zero the core of the surface light source formed in the near side,
Multipliers a and b, respectively as 0.1 r/sigma<=a <=0.4 r/sigma and 0.4 r/sigma<=b <=0.8 r/sigma The projection exposure approach characterized by making the quantity of light with the inside of the field of -a<=X<=a, the inside of the field of -b<=Y<=b and -a<=Y<=a, and -b<=X<=b smaller than other fields on said surface light source, or making it about 0.
[Claim 18] The projection exposure approach according to claim 17 characterized by making optical reinforcement in the field of X2+Y2 <=c2 smaller than other fields on said surface light source by making a multiplier c into 0.3 r/sigma<=c <=0.6 r/sigma, or being referred to as about 0.
[Claim 19] Said mask is the projection exposure approach given in any 1 term of claims 1-18 characterized by being a halftone phase shift mask.
[Claim 20] In the projection exposure approach which projects the pattern image of said mask on a sensitization substrate through projection optics while irradiating the illumination light through an illumination-light study system at a mask,
When irradiating the halftone phase shift mask characterized by providing the following, The optical Fourier transform side over the pattern side of said mask in said illumination-light study system, Or the 1st field set as each of four quadrants specified according to the rectangular coordinate system corresponding to said 2-way which makes an optical axis a zero on the near side, And the projection exposure approach characterized by lessening the quantity of light or setting it to about 0 except two or more 2nd fields mostly set as the equal distance from said zero corresponding to said 2nd element The 1st element which has periodicity in the 2-way which intersects said illumination light perpendicularly The 2nd element which has periodicity in the different direction from said 2-way

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[Translation done.]

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27/54	Ｚ	8102－2K			
		7352－4M	Ｈ０１Ｌ　21/30	３１１　Ｓ	
		7352－4M		３１１　Ｌ	

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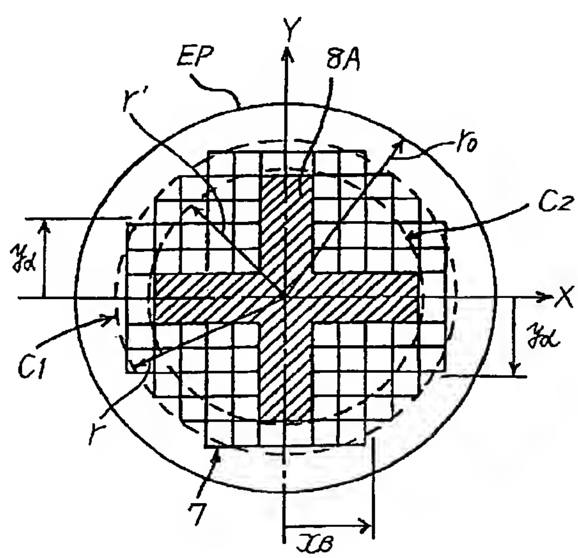
東京都千代田区丸の内３丁目２番３号　株式会社ニコン内

(54)【発明の名称】　投影露光装置

(57)【要約】
【目的】レチクル上の縦横周期パターンとともに斜め周期パターンの焦点深度も改善した変形光源を持つ投影露光装置を得る。
【構成】　４つの開口によって４光源を作る照明系において、コヒーレンスファクターσ値が０．８～０．６４の範囲を輪帯状面光源とし、σ値が０．６４以下の所で十字状遮光部を設けて４つの面光源を作る。



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【特許請求の範囲】

【請求項１】　投影すべきパターンが形成されたマスクを照明する照明系と、前記パターンの像を感光基板上に投影する投影光学系とを備えた投影露光装置において、前記照明系は、前記マスクのパターン面に対して光学的にフーリエ変換の関係となる面を内部に有する照明光学系と、前記フーリエ変換面上、もしくはその近傍面上で光軸を中心とした所定半径内に照明光を分布させる光分布設定手段とを含み；該光分布設定手段は前記光軸を中心とした所定幅の輪帯状の領域内に前記照明光を分布させるとともに、該輪帯状の領域の内側の中心部を除く離散的な複数部分の領域に前記照明光を分布させることを特徴とする投影露光装置。

【請求項２】　投影すべきパターンが形成されたマスクに照明光を照射するための光源と、前記マスクのパターン面に対して光学的にフーリエ変換の関係となる面が内部に形成され、該フーリエ変換面、もしくはその近傍面に前記光源の２次光源が作られる照明光学系と、該照明光学系からの照明光によって照射された前記マスクのパターンからの光を入射して、該パターンの像を感光基板上に結像投影する投影光学系とを備えた投影露光装置において、

前記マスク上のパターンが互いに直交する２方向の夫々に周期性を持つ第１のパターン形状と、該２方向の夫々と交差する方向に周期性をもつ第２のパターン形状とで形成され、前記マスク上で前記第１のパターン形状のしめる割合が前記第２のパターン形状のしめる割合よりも多いとき、前記第１のパターンの形状の周期性の方向に対応した傾斜照明光を作るように、前記フーリエ変換面、もしくはその近傍面上で前記照明光学系の光軸から所定量だけ偏心して互いに対称的に位置する４つの領域の夫々に第１の光源面を設定する第１設定部材と、

前記第２のパターン形状の周期性の方向に対応した傾斜照明光を作るように、前記フーリエ変換面、もしくはその近傍面上で前記照明光学系の光軸から所定量だけ偏心して互いに対称的に位置する４つの領域の夫々に第２の光源面を設定する第２設定部材とを備え、前記第１の光源面の面積を前記第２の光源面の面積よりも大きくしたことを特徴とする投影露光装置。

【請求項３】　前記第１設定部材と第２設定部材は、前記照明光学系のフーリエ変換面、もしくはその近傍面に配置された遮光板の透過部形状によって規定したことを特徴とする請求項第２項に記載の装置。

【請求項４】　前記照明光学系は前記光源面を作るフライアイレンズを含み、該フライアイレンズの射出面側に前記遮光板を配置したことを特徴とする請求項第３項に記載の装置。

【請求項５】　マスク上で直交する２方向に周期性をもって形成された第１のパターン形状と、それ以外の方向に周期性をもつ第２のパターン形状とを感光基板上に結像投影する投影光学系と、光源からの光を入射して所定半径の円形領域に包含される大きさの光源像を形成するフライアイレンズと、該フライアイレンズによる光源像を前記投影光学系の瞳面、又はその近傍面の中央に結像させるとともに、前記光源像内の各点からの光を前記マスク上で重畳させる集光光学系とを備えた投影露光装置において、

前記光源像の中心を原点として前記パターンの周期性の方向のうち互いに直交する２方向の夫々に対応した２つの座標軸を設定したとき、該２つの座標軸で規定される４つの象限の夫々にほぼ同一面積で形成された第１の透過部と、前記原点からほぼ等距離の位置で前記２つの座標軸上の夫々の４ヶ所に、ほぼ同一面積で形成された第２の透過部とを有する遮光板を前記フライアイレンズの射出側に配置し、前記第１パターン形状と第２パターン形状との重要度に応じて前記遮光板の第１の透過部と第２の透過部との面積を異ならせたことを特徴とする投影露光装置。

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【請求項６】　マスクのパターンを感光基板上に結像投影する投影光学系と、光源からの光を入射して、前記マスクに対する光学的なフーリエ変換面、もしくはその近傍面に所定形状の面光源を形成し、該面光源からの光を前記マスク上に一様に照射する照明光学系とを備えた投影露光装置において、

前記面光源の中心を原点として直交座標系ＸＹを定め、前記面光源の外形に近似した円の半径をｒ、前記面光源のコヒーレンスファクターをσ値としたとき、係数ａ、ｂをそれぞれ $0.1r/\sigma \leqq a \leqq 0.4r/\sigma$ 、 $0.4r/\sigma \leqq b \leqq 0.8r/\sigma$ として、前記面光源上で $-a \leqq X \leqq a$、かつ $-b \leqq Y \leqq b$ の領域内と $-a \leqq Y \leqq a$、かつ $-b \leqq X \leqq b$ の領域内との光強度を他の領域よりも小さくするか、もしくはほぼ零にする光強度分布調整部材を設けたことを特徴とする投影露光装置。

【請求項７】　前記光強度分布調整部材は、係数ｃを $0.3r/\sigma \leqq c \leqq 0.6r/\sigma$ としたとき、前記面光源上で、$X^2+Y^2 \leqq c^2$ の領域内の光強度を他の領域よりも小さくするか、もしくはほぼ零とすることを特徴とする請求項第６項に記載の装置。

【請求項８】　前記照明光学系は前記面光源の原点を前記投影光学系の瞳面の中心に結像するように構成され、該投影光学系の実効的な瞳径の前記面光源上での半径を r_o としたとき、前記面光源の半径ｒとの比 r/r_o であるσ値を、０．７以上にしたことを特徴とする請求項第６項又は第７項のいずれか１項に記載の装置

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、半導体集積回路、液晶表示素子等の微細パターンの露光転写に使用される投影露光装置に関し、特に転写すべきパターンの形成されたマスク（レチクル）の照明方法に工夫を施した露光装置

に関する。

【0002】

【従来の技術】年々微細化が進むリソグラフィ工程においては、現在、64MD－RAM製造用の実用的な投影露光装置の導入が必須となっている。このような微細なパターンの投影露光転写を十分な精度で達成するために、従来より様々の工夫が提案されている。そのうち、特に転写すべきパターンがライン・アンド・スペース（以下L＆Sとする）のように、ある方向に周期性をもつときに、従来よりも格段に解像力と焦点深度とを拡大させる手法として、特開平4－108612号公報、特開平4－225514号公報等のような超解像技術が提案された。

【0003】この超解像技術は、投影露光すべきL＆Sパターンが形成されたマスク基板（レチクル）への照明光の配向特性だけを特殊なものにすることで、従来の照明方法では解像しなかった微細なパターンを十分な焦点深度をもって解像させるものである。その照明光の配向特性は照明光学系内のレチクルに対するフーリエ変換面内での照明光束の分布、すなわち2次光源像の分布を、レチクルのL＆Sのパターンの微細度（ピッチ等）に対応して制御することによって作られる。

【0004】図1は、上記公報に開示された技術を適用した照明光学系の模式的な構成を示す斜視図である。ここでは照明光源として水銀ランプ1を用い、この水銀ランプ1の発光点を楕円鏡2の第1焦点に配置する。楕円鏡2で反射した照明光ＩＬａは第2焦点3で一度収れんした後、不図示のミラーで反射されてコリメータレンズ系4に入射する。一般に図1のように楕円鏡2と水銀ランプ1とを組み合わせると、照明光ＩＬａの断面は輪帯状（ドーナツ状）の強度分布をもつ。この輪帯状の断面の照明光ＩＬａはコリメータレンズ系4でほぼ平行光束に変換されて、照明系内のフーリエ変換面に配置された遮光板8に達する。遮光板8上には光軸ＡＸから等距離の位置に4つの開口が設けられ、この開口の夫々にはフライアイレンズ7Ａ、7Ｂ、7Ｃ、7Ｄが設けられる。これらフライアイレンズ7Ａ～7Ｄの夫々の入射面は、いずれも輪帯状断面の照明光束ＩＬａ内に位置する。また、フライアイレンズ7Ａ～7Ｄの夫々の射出側には、そのフライアイレンズ内のエレメントレンズの数分だけ、水銀ランプ1の点光源像が形成される。従って、フライアイレンズ7Ａ～7Ｄの各射出面には2次光源像（面光源）が形成される。

【0005】各フライアイレンズ7Ａ～7Ｄの夫々からの照明光は、コンデンサーレンズ等を含む逆フーリエ変換光学系11（以後便宜的にコンデンサーレンズと呼ぶ）によって、レチクルＲのパターン形成領域ＰＡ上に一様に重畳して照射される。レチクルＲのパターン領域ＰＡの中心に光軸ＡＸが通るように、レチクルＲを配置し、その中心を座標系ＸＹの原点としたとき、Ｌ＆Ｓ状のレチクルパターンは、多くの場合、Ｘ方向にピッチをもつＬ＆Ｓパターン（縦パターン）ＰｖとＹ方向にピッチをもつＬ＆Ｓパターン（横パターン）Ｐｈとに分けられる。すなわち、パターン領域ＰＡ内にはＸ方向とＹ方向との2方向について周期性をもつパターン群が集合して形成される。

【0006】Ｌ＆ＳパターンＰｖ、ＰｈのＸ、Ｙ方向のピッチのうち、最小のものに対して照明条件を最適化するものとすると、フライアイレンズ7Ａ～7Ｄの夫々の光軸ＡＸからの偏心量$y\alpha$、$x\beta$は、そのＬ＆Ｓパターンの最小ピッチと一義的な関係で決められる。例えばＬ＆ＳパターンＰｈのＹ方向の最小ピッチをGy（μm）、照明光ＩＬａの波長をλ（μm）、コンデンサーレンズ11からレチクルＲまでの距離、すなわち焦点距離をf（mm）とし、Ｌ＆ＳパターンＰｈから発生する1次回折光の回折角（0次光からの角度）を$2\theta y$（rad）としたとき、着目する1つのフライアイレンズのＹ方向の偏心量$y\alpha$は、$\sin 2\theta y=\lambda/Gy$、$y\alpha=f\cdot\sin\theta y$がほぼ同時に満たされるように決められる。

【0007】さらに、Ｌ＆ＳパターンＰｖのＸ方向の最小ピッチをGx（μm）とし、Ｌ＆ＳパターンＰｖから発生する1次回折光の回折角を$2\theta x$（rad）としたとき、着目する1つのフライアイレンズのＸ方向の偏心量$x\beta$は、$\sin 2\theta x=\lambda/Gx$、$x\beta=f\sin\theta x$がほぼ同時に満足するように決められる。以上のように、従来の特殊照明法（変形光源）では、レチクルＲ上のＬ＆Ｓパターンのうち、Ｘ方向にピッチを有するパターンＰｖの超解像投影には、フーリエ変換面上でＸ方向に対称的に偏心した2次光源像のペア（フライアイレンズ7Ａと7Ｄ、またはフライアイレンズ7Ｂと7Ｃ）からの傾斜照明光が寄与し、Ｙ方向にピッチを有するパターンＰｈの超解像投影には、フーリエ変換面上でＹ方向に対称的に偏心した2次光源像のペア（フライアイレンズ7Ａと7Ｂ、またはフライアイレンズ7Ｃと7Ｄ）からの傾斜照明光が寄与する。

【0008】尚、図1において第2焦点3には露光の開始と中断とを制御するロータリーシャッター等が配置され、第2焦点3はフライアイレンズ7Ａ～7Ｄの夫々の射出面側に形成される2次光源像と共役であり、フライアイレンズ7Ａ～7Ｄの夫々の入射面はレチクルＲのパターン面と共役になっている。

【0009】

【発明が解決しようとする課題】上記の如き従来技術においては、転写すべき回路原版（レチクル）の特定の方向、例えば直交する2方向の周期パターンについてのみ解像度や焦点深度を改善する効果がある。ところが、他の方向、特に上記の直交する2方向の夫々に対して45°回転した方向に周期性をもつパターンについては、通常の照明法を適用した露光装置よりも解像度や焦点深度が低下するという問題があった。

【0010】本発明は、このような問題に鑑みて成されたものであり、レチクル上の、特にレチクル外形と平行な縦横方向の夫々に周期性を有する2方向パターンの解像度と焦点深度を大幅に向上させつつ、これらとは方向の異なる斜め（例えば45°回転）パターンについても、通常の装置より高解像かつ大焦点深度が得られる投影露光装置の提供を目的としている。

【0011】

【課題を解決するための手段】本発明においては、投影露光装置のマスク照明用の照明光学系内のフーリエ変換面に形成される光源像（面光源）の2次元的な形状を、従来の形状に加えて若干変形するようにした。具体的には、図2に示すように、ほぼ円形の領域C1内に包含される面光源（ここではフライアイレンズ7の射出面）のうち、原点から所定半径の円C2よりも外側の輪帯部分は全く遮光しないようにする。そして、円C2の内側に原点からX、Y方向の夫々に延びた十字状遮光部8Aを設け、X、Y座標軸で規定された4つの象限の夫々に、互いに分離した透過部（光源面）を形成するようにした。その4つの象限の透過部は従来と同様にX、Y方向の夫々にピッチを有する周期性パターンの超解像に寄与する。

【0012】従来においては十字状遮光部8Aの4つの先端部が全て面光源の半径（ほぼ円C1の半径）以上に延設されていたが、本発明では十字状遮光部8の4つの先端部を面光源の半径よりも小さくし、それら4つの先端部の外側にも、面積的に小さな面光源が存在するようにした。尚、この図2中の直交座標系XYの設定は、図1のものと全く同じであり、座標系XYの原点は照明光学系、あるいは投影光学系の光軸AXと一致している。また、図2においてEPは、2次元光源像（面光源）としてのフライアイレンズ7の射出面内で見た投影光学系の瞳面を表す。

【0013】一般にこの種の投影露光装置では、投影光学系の瞳面（フーリエ変換面）内に面光源像（フライアイレンズ7の射出面の像）が形成されるようになっている。そして照明光学系内のフーリエ変換面上で見た投影光学系の瞳EPの半径r_0と、面光源の半径rとの比r/r_0のことはσ値と呼ばれる。そこで、図2において円C1の半径をσ値で0．7～0．8程度、円C2の半径r'を0．64r_0＝0．64r／σ程度にしておくと、X、Y方向の夫々に対して45°だけ回転した方向にピッチを有する0．4～0．45μmの線幅の周期パターンに対しても超解像の効果が十分に得られるようになる。尚、図2に示した円C1、C2の設定条件や十字状遮光部8Aの寸法条件については、以後の実施例において詳細に例示する。

【0014】

【作用】本発明においては、いわゆる変形光源の光源形状として、レチクル上の縦横パターンに最適化された部分を多く含みながら、かつ、斜めパターンについても最適な部分（図2の十字状遮光部8Aの先端の外側）も、わずかに含ませるようにした。このため、従来の変形光源ではむしろ通常照明より悪化してしまっていた斜めパターンの解像度及び焦点深度も、通常照明に比べて改善することができる。また、縦横パターンに最適化された光源部の面積（光量）と、斜めパターンに最適化された光源部の面積（光量）のバランスも最適化されているために、縦横パターンの投影時の解像度や焦点深度の改善も従来の変形光源形状の場合とほぼ同程度に実現できる。尚、図2のように十字状遮光部8Aの外側に輪帯状の面光源部（半径r'～r）を設けた場合、斜めパターンの周期性の方向はX、Y方向の夫々に対して必ずしも45°（又は135°）でなくても、本発明の効果が得られる。

【0015】

【実施例】図3は本発明の実施例による投影露光装置の全体的な概略構成を示す図である。そして、図3中の部材で、図1中のものと同じ機能のものには同一の符号を付してある。水銀ランプ1からの照明光ILaは楕円鏡2で第2焦点3に収れんされたのち、コリメータレンズ系4、ミラー5、インプット側フィールドレンズ6を介してフライアイレンズ7に入射する。第2焦点3の位置には一方向に回転するロータリーシャッター19Aが配置され、シャッター19Aは駆動ユニット（モータ、駆動回路等）19Bによって制御される。また、照明光ILaはフライアイレンズ7に入射する際、図1の場合と同様に輪帯状の強度分布をもつが、それはフライアイレンズ7の射出側に設ける遮光板（絞り）8の形状が、図2のような変形光源を作るものの場合に適している。しかしながら、遮光板8を従来と同様の円形開口絞りをもつ遮光板9に切り換えて通常照明を行う場合、照明光ILaの輪帯状の強度分布はあまり好ましくない。特にレチクルRが位相シフト法を適用したものの場合、レチクルRへの照明光の開口数は比較的小さな値（σ値で0．2～0．4程度）に絞られる。その場合、フライアイレンズ7の中央部分のエレメントレンズからの照明光、すなわち照明光ILaの輪帯状の強度分布の中央部の光のみがレチクル照明に利用されることになり、照度低下を招くことになる。

【0016】そこで通常照明に切り替えるときは、例えば USP. 4,637,691 等に開示されているようなプリズム30を、コリメータレンズ4とフィールドレンズ6との間に交換可能に配置し、照明光ILaの輪帯状の強度分布を円形状の分布に整形するとよい。さて、フライアイレンズ7の射出側には、図2のような変形光源用の遮光板8や通常光源用の遮光板9を交換可能に保持するターレット10が設けられる。ターレット10は駆動ユニット10Aによって、所定角度毎に回転させられる。図3では遮光板8がフライアイレンズ7の射出側に位置決め

されている。こうして遮光板８の透過部を通った照明光ＩＬｂはアウトプット側フィールドレンズ１３、ミラー１２を介してコンデンサーレンズ１１に入射する。フライアイレンズ７中の選ばれた複数のエレメントレンズの夫々の点光源からの光は、コンデンサーレンズ１１によって全てレチクルＲのパターン領域上で重畳して一様に照射される。図３中に示した照明光ＩＬａは、選ばれた１つのエレメントレンズの点光源からの光を代表して表したものである。

【００１７】ここで、遮光板８の遮光部形状とフライアイレンズ７のエレメントレンズ配置との関係は、図２に示したものと同じであり、現実的には図２中の円Ｃ１の外側も遮光部とし、十字状遮光部８Ａも含めて石英板等の透過板の上に金属層等を蒸着して作る。また、フライアイレンズ７の射出面（もしくは遮光板８の面）は、レチクルＲのパターン面に対して光学的なフーリエ変換の関係になっている。従ってフライアイレンズ７の１つのエレメントレンズで作られた点光源からの光は、コンデンサーレンズ１１によって入射角θの平行光束となってレチクルＲを傾斜照明する。このとき、１つの点光源のフーリエ変換面上での偏心量（光軸ＡＸからの距離）は、入射角θの正弦（$\sin\theta$）と比例関係にある。この入射角θは、レチクルＲ上の周期的なパターンのピッチに応じて適量値が存在する。Ｘ、Ｙ方向の夫々に周期的なパターンに対する偏心量$y\alpha$、$x\beta$の決定方法については、先の特開平４－２２５５１４号公報等に開示されているので、ここではその説明を省略する。

【００１８】照明光ＩＬｂの照射によって、レチクルＲ上の特定ピッチの周期パターンから発生した各回折光のうち、０次回折光D_0と１つの１次回折光D_1とは、両側テレセントリックな投影光学系ＰＬの瞳ＥＰ内で対称的に分布した後、ウェハＷに達する。従ってレチクルＲ上の特定ピッチの周期パターンは、１つの１次回折光D_1と０次回折光D_0との干渉によって作られる明暗像としてウェハＷ上に結像される。ウェハＷの表面にはレジスト層が塗布されているので、シャッター１９Ａの開時間を制御して、そのレジストに見合った最適露光光量を与えると、レチクルＲの周期パターンの縮小像がレジスト層に形成される。

【００１９】そのウェハＷは、光軸ＡＸと垂直な面内で２次元移動するステージＷＳＴ上に載置され、ステージＷＳＴはレーザー干渉計１８Ａによる座標位置の計測結果に基づいて、モータ等の駆動ユニット１８Ｂにより駆動される。制御ユニット２０は、そのウェハステージＷＳＴ、シャッター用駆動ユニット１９Ｂ、ターレット用駆動ユニット１０Ａを統括的に制御する。特にターレット用駆動ユニット１０Ａに対しては、レチクルＲの登録名による自動制御、またはオペレータからの指示による手動制御が可能となっている。

【００２０】図４は第１の実施例による遮光板８の具体的な形状を示す平面図であり、図５は図４中の座標系ＸＹと同一の座標系で見たときのレチクルＲ上の周期パターン配置を模式的に示したものである。図５に示したように、レチクルＲ上にはレチクルの外形各辺の方向Ｘ、Ｙと平行な周期的な縦パターンＰｖ（ピッチはＸ方向）と横パターンＰｈ（ピッチはＹ方向）とが多く存在し、それらにくらべて割合としては少ないが、Ｘ、Ｙ方向の夫々に対して４５°（又は、１３５°）回転した周期的な斜めパターンＴａ、Ｔｂも存在する。このようなパターンの構成は、本実施例に限らず、半導体デバイス用の回路原版としてのレチクルでは普通のことであり、縦パターンＰｖ、横パターンＰｈの割合は多く、斜めパターンＴａ、Ｔｂの割合は少ないのが一般的である。

【００２１】これらのパターンを有するレチクルＲに対して、図４に示した遮光板８を適用した照明光学系からの照明光を照射すると、幅２ａ、長さ２ｂの十字状遮光部８Ａによって区画された４つの扇状透明部８１ａ、８１ｂ、８１ｃ、８１ｄの夫々を面光源として、レチクルＲ上の縦パターンＰｖと横パターンＰｈとの投影時の解像度や焦点深度が従来と同様に向上する。ここで、遮光板８は最外周に外径値r_o、内径ｒの輪帯遮光部８Ｂを有し、原点（光軸ＡＸの通る点）から十字状遮光部８Ａの先端までの長さｂは、$r > b$の関係に設定されている。尚、輪帯遮光部８Ｂの内径エッジが図２中の円Ｃ１に相当し、輪帯遮光部８Ｂの外径値r_oが投影光学系ＰＬの瞳ＥＰの実効的な最大径（すなわち最大開口数N.A.）に対応するものとすると、輪帯遮光部８Ｂの内径値ｒと外径値r_oとの比r/r_oは、コヒーレンスファクターのσ値に他ならない。

【００２２】さらに、図４の遮光板８において、十字状遮光部８ＡのＸ、Ｙ方向の各先端部には、斜めパターンＴａ、Ｔｂの結像に有効な透明部８１ｅ、８１ｆ、８１ｇ、８１ｈが形成されている。従来のこの種の照明方法では、その４つの透明部８１ｅ、８１ｆ、８１ｇ、８１ｈは全て遮光部とされていた。この４つの透明部８１ｅ～８１ｈの夫々に光源像（面光源）を作ると、縦パターンＰｖや横パターンＰｈの投影時の解像度や焦点深度を多少劣化させる副作用がある。しかしながら、縦パターンＰｖ、横パターンＰｈに対して有効な扇状透明部８１ａ～８１ｄの個々の面積（あるいは光量）に比べて、４つの透明部８１ｅ～８１ｈの個々の面積（あるいは光量）は十分に小さいため、縦パターンＰｖや横パターンＰｈについての投影性能を大きく損なうものとはならない。

【００２３】ここで遮光板８の各値$r(\sigma)$、ａ、ｂの関係は、$0.1r/\sigma \leq a \leq 0.4r/\sigma$、$0.4r/\sigma \leq b \leq 0.8r/\sigma$程度に定められる。値ａが$0.1r/\sigma$（すなわち$0.1r_o$）よりも小さくなると、変形光源としての効果が消失し、通常照明（光軸ＡＸを中心とする単なる円形又は多角形面光源）と何ら変わらなくなる。さら

に、値ａが 0.4ｒ／σ（すなわち 0.4ｒ。）よりも大きくなると、４つの扇状透明部８１ａ～８１ｄの夫々の面積上の重心点が、遮光板８の原点から大きく離れた所に出来るため、レチクルＲ上のパターンＰｖ、Ｐｈのうちピッチがより微細になったものに対しては照明光の傾斜角の最適化がはかられるが、それよりもピッチが粗くなったパターンに対しては最適化がはかられず、焦点深度の拡大効果が得られにくくなる。

【００２４】また値ｂについても、 0.4ｒ／σより小さいと縦パターンＰｖ、横パターンＰｈの解像に不適当な面光源、すなわち透明部８１ｅ～８１ｈの面積が増大するため、縦横パターンＰｖ、Ｐｈの投影時の焦点深度が著しく減少してくることになる。逆に値ｂが 0.8ｒ／σより大きくなると、斜めパターンＴａ、Ｔｂの投影時の解像度や焦点深度の改善効果が薄らいでしまう。

【００２５】また図４に示した遮光板８の形状では、わずかながらも斜めパターンＴａ、Ｔｂの結像に有効な面光源部を含んでおり、かつ中央の十字状遮光部８Ａの大部分は縦パターンＰｖ、横パターンＰｈのみでなく、斜めパターンＴａ、Ｔｂに対しても不適当な面光源部をも遮光している。このため斜めパターンＴａ、Ｔｂの結像においても、従来の通常照明（光軸ＡＸを中心とする単なる円形又は多角形面光源）よりは格段に高い解像度や焦点深度を得ることができる。

【００２６】さて、図６は遮光板８の第２実施例による形状を示し、図４の遮光板８の構成と同じ部分には同一の符号を付けてある。本実施例は基本的には図４の遮光板と同じであるが、中央の十字状遮光部８Ａ’の中心に半径ｒ。（ｒ。＞ａ）の円形遮光部を設けた点が異なる。このように面光源の中心部を円形遮光部で遮へいすると、縦パターンＰｖ、横パターンＰｈの結像に関して特に有効な光源部、すなわち４つの扇状透明部８１ａ～８１ｄの夫々の面積が図４の場合よりも少なくなり、相対的に斜めパターンＴａ、Ｔｂの結像に関して有効な光源部、すなわち４つの透明部８１ｅ～８１ｈの夫々の面積の割合が増大する。この為、斜めパターンＴａ、Ｔｂの結像時の解像度や焦点深度を図４の場合よりもさらに改善することができる。

【００２７】また図６の遮光板８によって新たに遮光される部分は、比較的に光軸ＡＸに近い位置であり、やや粗め（例えばウェハ上での線幅が０．５μｍ以上）のピッチの縦パターンＰｖ、横パターンＰｈの結像時に焦点深度を改善する効果はあるものの、より微細なピッチの縦、横パターンＰｖ、Ｐｈに対しては解像度や焦点深度を改善する効果があまりない。そのため、投影露光すべきレチクルＲ上のＬ＆Ｓパターンが、比較的微細なピッチのものに限られていて、かつ同程度のピッチの斜めパターンも、少ないながらも適度の割合で含まれている場合、図６の遮光板８を用いた縦、横パターンＰｖ、Ｐｈの総合的な結像性能は、図４の遮光板８を用いたときと

比べて特に劣化することはない。

【００２８】ここで図６の遮光板８の中央の円形遮光部の半径ｒ２は、 0.3ｒ／σ≦ｒ２≦0.4ｒ／σ程度に定められ、厳密にはａ＜ｒ２＜ｂの条件も加味される。ここで半径ｒ２の値が小さくなって結局、ａ≧ｒ２となると、図４の遮光板８の形状と何ら変わらなくなってしまうため、斜めパターンＴａ、Ｔｂの結像時の焦点深度拡大作用はやや減少することになる。逆に半径ｒ２の値を大きくしていくと、その面光源形状は輪帯に近づくため、縦、横パターンＰｖ、Ｐｈの結像時の焦点深度拡大作用が減少してしまう。

【００２９】図７は遮光板８の第３実施例による形状を示し、基本的には図４の遮光板８の形状と同じであるが、外周の輪帯状遮光部８Ｂの内側で、４つの扇状透過部８１ａ～８１ｄの夫々の一部に９０°のコーナをもつ微少遮光部８Ｃ、８Ｄを設けた点が異なる。これら微少遮光部８Ｃ、８ＤはＸ軸、Ｙ軸の夫々と平行なエッジを有し、Ｘ軸からＹ方向に距離ｄｙだけ離れており、Ｙ軸と平行エッジはＹ軸からＸ方向に距離ｄｘだけ離れている。その微少遮光部８Ｃ、８Ｄは扇状遮光部８１ａ～８１ｄの夫々の中で、Ｘ軸、Ｙ軸の夫々から最も遠い部分に設けられており、この遮光部８Ｃ、８Ｄの部分からの照明光束は縦パターンＰｖ、横パターンＰｈとして最もピッチが小さいもの、あるいは微細なピッチの斜めパターンに対して最適化された配向特性を持つ。このため、そのように最もピッチが小さい縦、横パターン、あるいは微細な斜めパターンの結像時に、焦点深度拡大作用が得られる。ところが遮光部８Ｃ、８Ｄの部分から照明光束は、中程度（例えば０．４～０．５μｍの線幅）の微細度のＬ＆Ｓパターンの結像時に、むしろ焦点深度を減少させる方向に作用してしまう。

【００３０】従って図７の遮光板８は、ここでの変形光源方式によって理論上結像可能な最小ピッチ程度に微細な縦横パターンは含まないが、それよりも粗い中程度の微細度のＬ＆Ｓパターンを含むレチクルＲを投影露光するのに適していると言える。尚、図７から明らかなように、微少遮光部８Ｃ、８Ｄのエッジの距離ｄｘ、ｄｙは、ここではｄｘ＜ｒ、ｄｙ＜ｒに定められ、レチクル上の縦パターン、横パターン、斜めパターンの各ピッチがほぼ同程度であれば、さらにｄｘ＝ｄｙに定められる。そして図７の遮光板８内の扇状透明部８１ａ～８１ｄの夫々の面積的な重心点（光量重心点）の位置は、微少遮光部８Ｃ、８Ｄが存在しないときの重心点位置とそれ程変化していない。また微少遮光部８Ｃ、８Ｄの各エッジのＸ、Ｙ軸からの距離ｄｘ、ｄｙを小さくしていくと、各扇状透明部８１ａ～８１ｄは矩形（又は正方形）に近づいていく。

【００３１】図８は、微少遮光部８Ｃ、８Ｄの各エッジのＸ、Ｙ軸からの距離ｄｘ、ｄｙを比較的小さくするとともに、十字状遮光部８Ａ、輪帯状遮光部８Ｂ、微少遮

光部８Ｃ、８Ｄの夫々のエッジをフライアイレンズ7のエレメントレンズの断面形状（ここでは正方形とする）に合わせた場合の遮光板８の形状を示す。尚、先の図４、図６、７の各遮光板の場合も遮光部エッジはエレメントレンズの断面形状に合わせるのが好ましい。図８において、斜めパターンＴａ、Ｔｂの結像時に有効な光源部分を形成する４つの透明部８１ｅ～８１ｈ夫々には、２個のエレメントレンズがX軸、Y軸をはさんで位置する。また、十字状遮光部８Ａの幅の半値ａはエレメントレンズの１個分の寸法に定められ、長さｂは5個分の寸法に定められている。そして扇状透明部８１ａ～８１ｄの夫々には、４×４個のエレメントレンズの集合から最外角の１個のエレメントレンズを取り除いたものが位置する。尚、微少遮光部８Ｃ、８Ｄに相当する部分は、それぞれ2個のエレメントレンズを遮へいしている。また、この図の遮光板８の場合、４つの扇状透明部８１ａ～８１ｄと透明部８１ｅ～８１ｈとは、今までの各実施例のようにつながっておらず、互いに独立したものとなっている。さらに４つの扇状透明部８１ａ～８１ｄの夫々の最内角（最も原点に近い隅）に位置する１個のエレメントレンズを遮へいするように、すなわち中心部に４×４個のエレメントレンズの集合体の大きさと同じ正方形（又は矩形）の遮光部を付加してもよい。このような正方形の遮光部の付加によって、先の図６に示した第２の実施例の遮光板８と同様の作用、効果を得ることができる。この場合、中心の四角形遮光部の各辺のエッジのX軸、Ｙ軸からの距離は、図６の円形遮光部の半径Cと同程度の範囲に定められる。

【００３２】さらに図８中に示した扇状透明部８１ａ～８１ｄの夫々に位置するフライアイレンズ7のエレメントレンズ群は、全てX軸、及びY軸に対して対称な配置になっている。このような対称配置を採ることによって、レチクル上のL＆Sパターンの投影像のテレセン誤差（ベストフォーカス面からウェハ面がわずかにずれたときの像の横ずれ）が皆無となる。

【００３３】ここで図９を参照して、図４、図６～８の遮光板8を用いたとき、レチクルRから発生して投影光学系ＰＬに入射した結像光束の瞳面ＥＰ内での分布について説明する。図９は図２に対応して表したもので、所定のピッチの縦、横パターンＰｖ、Ｐｈに対して最適化された４つの扇状面光源部の光量重心点８０Ａ、８０Ｂ、８０Ｃ、８０Ｄと、その縦、横パターンＰｖ、Ｐｈと同一のピッチの斜めパターンＴａに対して最適化された4つの光量重心点のうちの代表的な１つの重心点８０Ｅとを、瞳面ＥＰ上で示したものである。４つの重心点８０Ａ～８０Ｄの夫々は、各実施例中の４つの扇状透明部８１ａ～８１ｄの夫々の面積的な重心とほぼ一致しており、重心点８０Ｅは透明部８１ｅの面積的な重心点とほぼ一致している。まず、４つの重心点８０Ａ～８０Ｄは、対象となる縦、横パターンのピッチに対して最適化されているので、例えばレチクルRからの結像光束のうち、重心点８０Ａを通る照明光線の照射によって縦、横パターンから発生する０次光は、重心点８０Ａを通り、±１次回折光の一方は、Ｘ軸、Ｙ軸の夫々と対称に位置する重心点８０Ｂ、８０Ｄを重畳して通る。

【００３４】一方、重心点８０Ｅを通るように配向された照明光線によって縦パターンＰｖから発生する±１次回折光$\pm Dx_1$（回折光束の重心）は、重心点８０Ｅを通りX軸と平行な線上に分布するが、その位置は図９のように瞳面ＥＰの最大径の外側になってしまうので、縦パターンＰｖの結像には影響を与えない。ところが横パターンＰｈから発生する１つの１次回折光$-Dy_1$（回折光束の重心）は瞳ＥＰ内のY軸上に分布するため、横パターンＰｈの結像に影響を与える。この１次回折光$-Dy_1$は横パターンＰｈの変形照明法による理想的な分布位置とは異なるため、横パターンＰｈの結像にとってはあまり好ましくない光である。しかしながら、重心点８０Ｅを作る照明光量は、小さな面積の透明部８１ｅで決まり、他の４つの重心点８０Ａ～８０Ｄの照明光量に比べて格段に小さい。その比は例えば図８の場合、フライアイレンズ７のエレメントレンズの数の比で決まり、そのため、好ましくない１次回折光$-Dy_1$の光量自体も格段に小さく、横パターンＰｈの結像性能を実用上大きく劣化させることはない。

【００３５】次に斜めパターンＴａ（４５°）からの結像光束の分布について考えてみる。ここでは、代表して重心点８０Ｂを０次光が通るように配向された照明光（扇状透明部８１ｂの透過部）の照射によって斜めパターンＴａから発生する回折光について述べる。斜めパターンＴａのピッチが縦、横パターンＰｖ、Ｐｈのピッチと同程度であるとすると、斜めパターンＴａからの１次回折光$-Dt_1$（回折光束の重心）は、重心点８０Ｂを中心とした半径$2y\alpha$（あるいは$2x\beta$）の円上で、かつ重心点８０Ｂと８０Ｂとを光軸ＡＸを通って結ぶ線（１３５°）上に位置する。この１次回折光$-Dt_1$は、２つの重心点８０Ａ、８０Ｃを結ぶ４５°の線に関して、重心点８０Ｂを通る０次光束と対称的な関係になっていないために、斜めパターンＴａの結像に対しては好ましくない光になっている。

【００３６】ところが、重心点８０Ｅに斜めパターンＴａからの０次光が位置するように、、遮光板８に透明部８１ｅが設けられているので、透明部８１ｅからの照明光によって斜めパターンＴａから発生した１次回折光$-Dt_1'$は、重心点８０Ｅを中心とした半径$2y\alpha$（あるいは$2x\beta$）の円上で、かつ重心点８０Ｅを通る１３５°の線（重心点８０Ｂと８０Ｄを結ぶ線と平行）上に位置する。その重心点８０Ｅと１次回折光$-Dt_1'$との位置関係は、重心点８０Ａと８０Ｃとを結ぶ４５°の線（斜めパターンＴａのフーリエ変換像における中心軸）に対してほぼ対称になっている。従って、透明部８

１ｅからの照明光は、斜めパターンＴａの結像に対して有効な成分になり、斜めパターンの解像度や焦点深度を改善する方向に働く。尚、図９の場合、重心点８０Ｅを０次光とする斜めパターンＴａからの１次回折光－Ｄｔ₁’はほぼＸ軸上に位置し、さらにその位置は遮光板８の斜めパターン用の他の透明部８１ｈからの照明光の重心点（８０Ｈとする）に接近している。このように、１次回折光－Ｄｔ₁’の位置に透明部８１ｈの重心点８０Ｈが位置することは、斜めパターンＴａがそのピッチ方向に対称的に傾斜した２つの照明光束で照明されることを意味する。

【００３７】以上のことから、投影露光すべき縦、横パターンＰｖ、Ｐｈ、斜めパターンＴａ、Ｔｂの各ピッチが１枚のレチクル上で同程度とすると、斜めパターン用に付加した面光源部（透明部８１ｅ～８１ｈ）の夫々の光量重心点は、理想的にはＸ軸、Ｙ軸上で原点から、$\sqrt{(x\beta^2 + y\alpha^2)}$の距離の所に配置すればよい。この関係は理想的な条件であって、現実的にはその関係から若干（例えば２０％～３０％程度）はずれていても、本発明の効果はそれなりに得られる。

【００３８】図１０は本発明の第４の実施例による照明光学系の部分構成を示し、ここでは図３に示したフライアイレンズ７の部分を、特公平３－７８６０７号公報に開示されているような２連のフライアイレンズ系に変更する。　図３中のコリメータレンズ４とプリズム３０とを通った照明光ＩＬａは、図１０のように１段目のフライアイレンズ７Ｅに入射する。このフライアイレンズ７ＥはＸ、Ｙ方向に４個ずつのエレメントレンズを束ねたものとする。フライアイレンズ７Ｅの各エレメントレンズの射出端に結像した点光源像の夫々からの照明光は、レンズ系２５を介して２段目のフライアイレンズ７Ｆの入射面の全面を重畳して照射する。２段目のフライアイレンズ７Ｆは６×６個の配列でエレメントレンズを束ねたもので、各エレメントレンズの射出面から数ｍｍ程度離れた空間中に３次元光源像（点光源）が結像される。この２連フライアイレンズ系の場合、２段目のフライアイレンズ７Ｆの個々のエレメントレンズの射出側には、１段目のフライアイレンズ７Ｅの射出面に形成された４×４個の点光源像が形成されるので、３次元光源像は１６×３６個の点光源が２次元的に集合した面光源となる。

【００３９】さて、本実施例の場合、図４、図６～８に示した遮光板８は、２段目のフライアイレンズ７Ｆの射出側で、３次元光源像が形成される空間中の面内に配置される。図１１はフライアイレンズ７Ｆの射出側に形成された３次元光源像と遮光板８の遮光部８Ａ（８Ａ’）、８Ｂの各エッジとの配置関係を示したものである。図１１に示すように、フライアイレンズ７Ｆの１つのエレメントレンズの射出側には、４×４個の点光源ＳＰがＸ、Ｙ方向にほぼ等ピッチで整列している。このとき、十字状遮光部８Ａ（８Ａ’)の外形エッジや周辺の輪帯状遮光部８Ｂの内径円Ｃ１に対応するエッジは、全て３次元光源像を形成する点光源のピッチに合わせて屈曲される。すなわち、単一のフライアイレンズ系のときは図８に示したようにフライアイレンズのエレメントレンズの断面形状に合わせて各遮光部のエッジを規定する必要があったが、２連（タンデム）フライアイレンズ系では、そのような必要がない。しかも３次元光源像を形成する点光源の数は、単一フライアイレンズ系の場合よりも格段に増えているため、面光源としての平均的な照度分布は極めて平坦になる。

【００４０】図１２は本発明の第５の実施例によせる照明系の構成を示し、ここでは特開平４－２２５５１４号公報に開示されているように、照明系内のフーリエ変換面上のＸＹ座標系で４つの象限の夫々に位置する縦横パターン用の面光源を、それぞれ独立したフライアイレンズ７０Ａ、７０Ｂ、７０Ｃ、７０Ｄで構成する。そしてコリメータレンズ４からの輪帯状分布の照明光束を四角錐プリズム２６で４つの光束に分割し、それぞれを４つのフライアイレンズ７０Ａ～７０Ｄへ入射する。また、斜めパターン用の面光源は、４本のオプチカルファイバー９０の先端部７０Ｅ、７０Ｆ、７０Ｇ、７０Ｈで構成し、その４本のオプチカルファイバー９０の他端（入射端）側は１本に束ねられ、シャッター１９Ａの後で分岐された照明光の一部がその入射端に集光される。

【００４１】本実施例では斜めパターン用の面光源を作る系が、縦横パターン用の面光源を作る系と独立しているので、投影対象となったレチクル上に斜めパターンが全く存在していないときは、オプチカルファイバー９０の入射端側の光路中に別のシャッターや減光フィルター（ＮＤフィルター）を挿入して、先端部７０Ｅ～７０Ｈの発光を禁止するか、大幅に光量低下させることができる。さらに、そのＮＤフィルターの減光率の調整等によって先端部７０Ｅ～７０Ｈの発光強度を変化させることができるので、レチクルＲ上のＬ＆Ｓパターンのうち斜めパターンがしめる割合に応じて最適な光量を与えることができる。従って、オペレータがレチクルＲ上の斜めパターンの割合に関する情報を、図３中の主制御ユニット２０に入力する構成にしておけば、４つの先端部７０Ｅ～７０Ｈの発光強度を、予め定められたテーブルに従って自動的に最適値（零も含む）に調整することもできる。　また、図１２に示したように、４つのフライアイレンズ７０Ａ～７０Ｄ、４つの先端部７０Ｅ～７０Ｈが独立に設けられるから、レチクルＲ上のＬ＆Ｓのパターンのピッチに応じて、個々のフライアイレンズ、または先端部をＸＹ面内で２次元、または１次元に可動にしておいてもよい。その場合、縦横パターン、斜めパターンのピッチが同程度であり、４つのフライアイレンズ７０Ａ～７０Ｄの夫々の射出側の面光源の光量重心点が、ＸＹ面内で光軸ＡＸを中心とする正方形の４隅に対応した

配置をとるときは、４つのフライアイレンズ７０Ａ～７０Ｄの光量重心点の光軸ＡＸからの偏心量と、先端部７０Ｅ～７０Ｈの光量重心点の光軸からの偏心量とがほぼ等しくなるような関係で可動にするとよい。

【００４２】尚、図１２の構成において、４つのフライアイレンズ７０Ａ～７０Ｄの夫々は、図１０と同様にタンデム・フライアイレンズ系としてもよく、また各フライアイレンズ７０Ａ～７０Ｄの夫々の射出側に個別に絞り（遮光板）を設け、４つの面光源のそれぞれの大きさを個別に、又は連動して変えられるようにしてもよい。ところで図１２において、フライアイレンズ７０Ａ～７０Ｄの夫々の間には、特別に遮光板等を設けていないが、各フライアイレンズの間の空間を通ってくる迷光が無視できない程に多いときは、簡単な遮光板（十字状）を設けるのが望ましい。従ってその迷光成分が十分に小さければ、特別に遮光板を設ける必要はない。このことは、先の図４、図６～８に示した遮光板８に対しても同様に適用できることであって、十字状遮光部８Ａ、８Ａ’や輪帯状遮光部８Ｂ等を完全な遮光層にしなくてもよいことを意味する。例えば遮光板８上の各遮光部を、露光用の照明光の波長（ｉ線では３６５ｎｍ、ＫｒＦエキシマレーザでは２４８ｎｍ）において９０％以上の減光率をもつ誘電体薄膜等で構成してもよい。

【００４３】さて、ここで以下のシミュレーションの説明のために、これまでに発表されている従来の変形光源の絞り形状の例を図１３、１４に示す。図１３は特定のピッチを有する縦パターンＰｖ、横パターンＰｈに最適化された中心位置（ｘβ、ｙα）と、適当な半径（σ値で０．１～０．３）を有する円形４光源用の遮光板の例である。図１４は図１３の円形開口の代わりに夫々正方形の開口とし、かつそれら４つの正方形開口の周辺の一部が照明光学系のσ値に相当する半径ｒより大きい扇状４光源用の遮光板の例である。

【００４４】一例として、図１４に示す光源形状を用いた縦横Ｌ＆Ｓパターン、及び斜め（４５°または１３５°方向）Ｌ＆Ｓパターンの投影時に得られるＬ＆Ｓパターン像のライン、又はスペースの線幅サイズ〔μｍ〕に対する焦点深度ＤＯＦ〔μｍ〕のシミュレーション結果を図１５に示す。ここでシミュレーションの条件は、波長λをｉ線の０．３６５〔μｍ〕、投影光学系ＰＬのウェハ側の開口数 N.A. を０．５０（レチクル側では０．１）、遮光板８の輪帯状遮光部８Ｂの内径ｒをσ値（ｒ／ｒ。）として０．８（通常の円形面光源のσ値も０．８とする）、十字状遮光部の幅の半値ａを開口数換算で０．２８、すなわちａ＝０．２８ｒ／σ＝０．３５ｒとした（通常照明ではａ＝０で十字状遮光部なし）。ここで焦点深度（ＤＯＦ）の値は、１：１ラインアンドスペース（Ｌ／Ｓ）パターン像のコントラストが６０％以上になる範囲（全幅）から、パターンニングすべきレジストの厚さ１．２μｍ、その屈折率１．７によって決まる一定値、１．２／１．７≒０．７０６〔μｍ〕を差し引いた値とした。図１５中で２点鎖線で表したシミュレーション結果の特性ＤＶ１は、図１４の従来の遮光板を用いたときの縦、横Ｌ＆Ｓパターンに対する焦点深度特性を示し、破線のシミュレーション特性ＤＯ１は、同様に図１４の遮光板を用いたときの斜め（４５°、１３５°）Ｌ＆Ｓパターンに対する焦点深度特性を示す。図１４の如き従来の変形光源形状では、斜めパターンに対する焦点深度特性ＤＯ１が、比較のためにシュミレートした通常の円形面光源を用いたときの斜めパターンに対する焦点深度特性ＤＣよりわずかに劣る結果となる。尚、通常の円形光源形状の場合は縦、横、斜めパターンのいずれに対しても焦点深度特性ＤＣになる。

【００４５】図１６は本発明の第１実施例（図４）による遮光板８を用いたときの焦点深度特性のシミュレーション結果を示す。このとき、図４中の十字状遮光部８Ａの幅の半値ａはａ＝０．２８ｒ。＝０．３５ｒに定められ、長さの半値ｂはｂ＝０．５６ｒ。＝０．７ｒとし、露光波長λ、N.A.、σは図１５の場合と同じにした。この条件での縦横の１：１のＬ＆Ｓパターンでの焦点深度特性ＤＶ２は、図１５中の従来の変形光源（図１４）による特性ＤＶ１よりわずかに劣るが、一方斜めＬ＆Ｓパターンに対する焦点深度特性ＤＯ２は、通常の円形面光源を用いたときの焦点深度特性ＤＣより上まわっており、本発明の効果が確認されている。また、縦横パターンに対する焦点深度特性ＤＶ２も十分にあり、変形光源が本質的に持つ能力を損なうものではない。尚、本シミュレーションでは、十字状遮光部の幅の半値ａと長さの半値ｂをそれぞれａ＝０．２８ｒ。（投影光学系の開口数N.A.の０．２８倍）、ｂ＝０．５６ｒ。（開口数 N.A.の０、５６倍）としたが、これらの値はそれに限定されるものではなく先に述べたように、値ａは 0.1r。(0.1・N.A.) ≦ａ≦ 0.4r。(0.4・N.A.) 程度であればよく、値ｂについては 0.4r。(0.4・N.A.) ≦ｂ＜ 0.8r。(0.8・N.A.) 程度であれば、本発明の効果を得ることができる。ただし、値ｂの上限は、半径ｒの値に対してｂ＜ｒになっている必要がある。

【００４６】図１７は本発明の第２の実施例（図６）による遮光板８を用いたときの焦点深度特性のシミュレーション結果を示す。このとき遮光板８は図６に示した通り、十字状遮光部と中心円形遮光部とを組み合わせたもので、シミュレーション条件は露光波長λを０．３６５μｍ（ｉ線）、投影光学系ＰＬのウェハ側開口数N.A.を０．５０、遮光板８の外周の輪帯状遮光部８Ｂの内径ｒをσ値（ｒ／ｒ。）換算で０．７、十字状遮光部の幅の半値ａを０．２８ｒ。、長さの半値ｂを０．５６ｒ。、そして中心円形遮光部の半径ｃを０．４６ｒ。とした。図１７のシミュレーション結果のように、斜めＬ＆Ｓパターンの焦点深度特性ＤＯ３は、従来の通常の円形面光源（σ＝０．７）での焦点深度特性ＤＣに比べて格段に

改善されており、かつ、縦、横のＬ＆Ｓパターンに対する焦点深度特性ＤＶ３も十分に大きな値となっている。
【００４７】ここでのシミュレーションでは、中心円形遮光部の半径ｃの値を０．４６ｒ／σとしたが、これも前述の半値ａ、ｂ同様、０．４６ｒ／σに限定されるわけではなく、0.3r／σ（0.3・N.A.）＜ｃ＜0.6r／σ（0.6・N.A.）程度であれば本発明の効果を十分に得ることができる。ただし、半径ｃの値があまりにも小さいと、図６の遮光板８は図４の遮光板と同様の形状となるため、斜めパターンについての焦点深度の改善度はやや減少することになる。すなわち、図１７中の特性ＤＯ３が、図１６中の特性ＤＯ２のようになる。また、半径ｃの値があまり大きいと、それは輪帯照明（後述）に近づくため、縦横のＬ＆Ｓパターンに対する焦点深度特性ＤＶ３中で、パターンサイズが０．４５μｍ付近に見られるような焦点深度が特に大きくなる部分が存在しなくなり、やはり望ましくない。
【００４８】図１８は本発明の第３の実施例（図７）による遮光板８を用いたときのシミュレーション結果を示す。この場合のシミュレーション条件は、投影光学系の開口数 N.A. を０．５０、面光源の最大半径であるσ値（ｒ／r_o）を０．８、十字遮光部８Ａの各寸法、半値ａ、半値ｂをそれぞれ０．２８r_o、０．５６r_o、そして周辺の微小遮光８Ｃ、８Ｄまでの距離ｄを０．６４r_oとした。この図１８のシミュレーション結果と、前述の図１６に示したシミュレーション結果とを比べると、図７の遮光板８を用いたときの斜めパターンについての焦点深度特性ＤＯ４は、図４の遮光板８を用いたときの焦点深度特性ＤＯ２（図１６）、又は図６の遮光板を用いたときの焦点深度特性ＤＯ３（図１７）と同程度に改善されていながら、縦横のＬ＆Ｓパターンのうち、特に０．４５μｍ程度のライン幅の中程度の微細度のパターンについても、焦点深度特性ＤＶ４の如く、焦点深度が改善されることがわかる。
【００４９】尚、図７の遮光板中の微小遮光部８Ｃ、８Ｄのエッジ距離ｄの値も、０．６４r_oに限定されるわけではなく、０．５r_o＜ｄ＜０．８r_o程度の範囲であればよい。ただし距離ｄがあまり小さいと縦横パターンに対する解像度が低下してしまうことになり、あまり大きいと効果が表れない。そこで図７に示した遮光板８の光軸近傍をさらに遮光する図６のような中心円形遮光部、あるいは四角形遮光部を追加してもよい。
【００５０】図１９は比較のために輪帯照明での同様のシミュレーション結果を示すものである。このときの条件は露光波長λを０．３６５μｍとし、そして０．７・N.A.（σ＝０．７）に相当する半径の円形面光源のうち、その半分の半径（σ＝０．３５）に相当する中心円形部を遮光部とした輪帯状面光源を考える。このような輪帯照明で得られるＬ＆Ｓパターンに対する焦点深度特性ＤＡでは、０．４２μｍ以上のライン（又はスペース）幅をもつ粗いパターンについて、幅でほぼ１．５μｍ程度の焦点深度が得られる。従来の円形面光源のときの焦点深度特性ＤＣでは１μｍもないのが実情である。ただし、実際のメモリーパターンの露光時を考えると、特に金属配線層の露光工程では大きな焦点深度が要求され、例えば６４ＭＤＲＡＭでは０．４５μｍ程度の線幅のＬ＆Ｓパターンに対して、幅で２μｍ以上の焦点深度が必要とされる。従って図１９の如く輪帯照明で得られる焦点深度特性ＤＡではこの要求を満たすことは難しい。また、上述の金属配線層の露光工程でも、特に焦点深度が必要とされているのは段差（１μｍ程度）部に形成されている縦、横のＬ＆Ｓパターンであるため、本発明のような変形光源形状はきわめて有効なものである。
【００５１】尚、実施例中においては、光源を水銀ランプとしてｉ線を用いるものとしたが、これは他の波長であってもレーザ等の光源であってもよい。またシミュレーションの条件では、投影光学系の開口数 N.A. を０．５とし、遮光板によって作られる最大の面光源の半径ｒをσ値で０．７、又は０．８としたが、開口数 N.A.、σ値はこれに限定されるものではない。ただしσ値については、０．７以上程度が効果的である。また光源形状の最外形は、遮光板８の輪帯遮光部８Ｂの内径エッジで規定される円（σ）によって制限されるものとしたが、その最外形は四角形、六角形等で規定してもよい。さらに各実施例中の遮光板８の遮光部形状はＸ方向、Ｙ方向に関して同形状（対称形）としたが、その形状はＸ方向とＹ方向とで異なってもよい。すなわち、各遮光部の寸法値ａ、ｂ、ｄ、あるいは中心に四角形遮光部を設けた場合の各エッジの中心からの距離ｃの値が、Ｘ方向とＹ方向とで異なってもよい。
【００５２】実際の照明系中では、フライアイレンズの射出面の光量分布はフライアイレンズの各エレメントレンズの配列に応じて離散的、すなわち点光源の離散的な集合となる。このとき、各エレメントレンズの断面形状が長方形であると、離散的な点光源のそれぞれの間隔もＸ、Ｙ方向で異なってくる。そこで実効的な照明条件（レチクルへの照明光の配向特性）をＸ、Ｙ方向で揃えるために、各遮光部の寸法値ａ、ｂ、ｃ、ｄの値をＸ、Ｙ方向で積極的に異ならせることが必要となることもある。また、本発明の各実施例で用いる遮光板８の各透過部８１ａ～８１ｄ、８１ｅ～８１ｈに対して効率よく照明光を集中させて光量損失を減らすために、遮光板８の前に、それらの透過部に照明光を集中させる集光手段（プリズム、ミラー、ファイバー等）を設けるとよい。さらに各実施例の遮光板８は透過部と遮光部より成るとしたが、遮光部の一部、または全てを半透過部（望ましくは透過率が５０％以下）としてもよい。また、露光を行う工程によって、必要な焦点深度や縦横パターンと斜めパターンの重要度が異なるため、それらに対応できる形状をもった複数の遮光板８を、図３のターレット１０

に用意し、交換使用可能としておくことが望ましい。シミュレーションにおいては、使用するレチクルを遮光部（クロム層）と透過部から成る通常のレチクルとしたが、本発明を、いわゆるハーフトーン位相シフト（遮光部の代わりに1～15％程度の透過率を持ち、かつ透過部を通る光との間の位相をπだけ異ならしめるハーフトーン透過部（薄膜）を設ける）方式のレチクルの投影時に用いると、本発明の効果をさらに高めることができる。

【0053】以上の各シミュレーション結果から明らかなように、縦横パターンPv、Phのウェハ上での線幅が、64M－DRAM製造時に使われる0．4～0．5μm程度のとき、各実施例に示した遮光板8は焦点深度の改善に良好に作用している。しかも、同時に斜めパターンTa、Tbについても焦点深度の改善効果が得られている。ただし縦横パターンと斜めパターンとで同じ線幅サイズでの焦点深度を比べてみると、確かに斜めパターンの方の焦点深度はそれ程大きくない。しかしながら、1枚のレチクル内での縦横パターンのピッチ（線幅サイズ）に対して、斜めパターンのピッチ（線幅サイズ）の方が1．2～1．5倍程度粗い場合、例えば図17中の縦横パターンに対する特性DV3中で線幅サイズが0．42μmのとき、斜めパターンの線幅サイズがその1．5倍（0．63μm）であると、斜めパターンに対する特性DO3中の線幅サイズ0．63μmでの焦点深度は2μm程度得られることになる。

【0054】ところで先の図9から明らかなように、対象とする縦横パターンのピッチに対して最適化された4つの光量重心点（0次光の重心点）80A～80Dが、投影光学系PLの瞳EP内で正方形の各角に位置するとき、対象とする斜めパターンのピッチが縦横パターンのピッチの約1．4倍程度である場合、斜めパターン用に補助的に加えられる照明光の光量重心点80Eは、理想的には2つの重心点80A、80Bを結ぶ線分とY軸との交点に一致する。

【0055】図20は、縦横パターンと斜めパターンとのピッチ関係とが上述のように約1．4倍になっているときに、ほぼ理想的な関係で各光量重心点を配置した様子を示す。この図20中で、瞳EPに分布する0次光、1次回折光は各重心点の回りに所定の大きさで広がりを持つものとする。その広がりの形（領域）は、本来、遮光板8の透明部81a～81d、81e～81h等の面光源の形状に一致するが、ここでは単に円形で表してある。

【0056】図20の場合、斜めパターン（45°、135°）から発生する4つの0次光（重心点80A～80D）の夫々に対応した1次回折光$-Dt_1$は、瞳EPのほぼ中心を重畳して通る。また、重心点80Eを0次光として通る斜めパターンからの1次回折光$-Dt_1'$は、斜めパターン用の補助光源の重心点80Hと80Fの夫々の近傍、又は一致した位置を通る。同時に、重心点80Eを0次光として通る横パターンからの1次回折光$-Dy_1$は、斜めパターン用の補助光源の重心点80Gの近傍、又は一致した位置を通る。

【0057】このような0次光、1次回折光の分布のうち、変形光源を用いたときの斜めパターンに対する焦点深度拡大効果を低減させる成分は、瞳EPの中心に現れる4つの1次回折光$-Dt_1$である。そこでこのような条件のときには、投影光学系の瞳EPの中央部のみに減光フィルター（NDフィルター）を配置し、4つの1次回折光$-Dt_1$の光量を適度に減衰させるとよい。

【0058】尚、図20中の縦横パターン用の4つの光量重心点80A～80Dを作る円形領域と、斜めパターン用の4つの光量重心点80E～80Hを作る小さな円形領域との配置関係は、そのまま照明系内に設ける変形光源用の遮光板8の透明部形状と相似になる。従って遮光板8として、図20中の4つの大きな円形領域と4つの小さな円形領域とを透明にした形状のものがそのまま使える。

【0059】

【発明の効果】以上のように本発明によれば、これまで変形光源で問題とされていた斜めパターンに対する結像性能、特に焦点深度改善度の劣化を防止することができ、また縦横パターンについても従来の変形光源とほぼ同様の性能を得ることができる。

【図面の簡単な説明】

【図1】本発明の基礎となる変形光源を持った照明系の斜視図。

【図2】本発明による変形光源の原理的な形状を示す図。

【図3】本発明の実施例としての投影露光装置の全体構成を示す図。

【図4】第1の実施例による変形光源用の遮光板の形状を示す図。

【図5】レチクル上のL＆Sパターンの周期方向の一例を示す図。

【図6】第2の実施例による変形光源用の遮光板の形状を示す図。

【図7】第3の実施例による変形光源用の遮光板の形状を示す図。

【図8】図7の遮光板の形状とフライアイレンズとの配置関係の一例を示す図。

【図9】各実施例に示した変形光源を用いたときの、投影光学系の瞳面での光束分布を模式的に示す図。

【図10】第4の実施例による照明系の一部の構成を示す図。

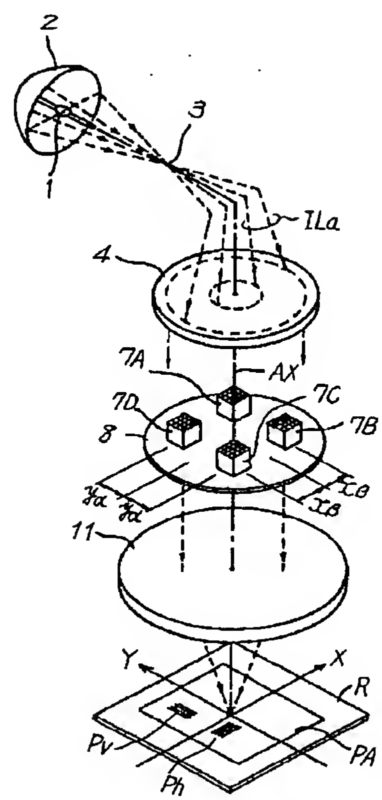
【図11】図10の照明系に好適な遮光板の形状を示す図。

【図12】第5の実施例による照明系の一部の構成を示す図。

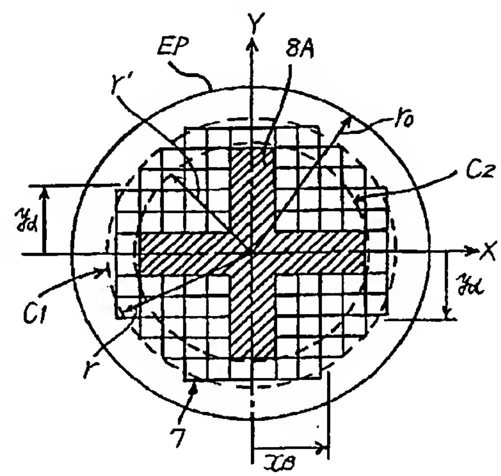
【図１３】従来の変形光源用の遮光板の形状を示す図。
【図１４】従来の変形光源用の遮光板の形状を示す図。
【図１５】図１４の遮光板を用いたときの焦点深度特性のシミュレーション結果を示すグラフ。
【図１６】図４の遮光板を用いたときの焦点深度特性のシミュレーション結果を示すグラフ。
【図１７】図６の遮光板を用いたときの焦点深度特性のシミュレーション結果を示すグラフ。
【図１８】図７の遮光板を用いたときの焦点深度特性のシミュレーション結果を示すグラフ。
【図１９】輪帯照明を行ったときの焦点深度特性のシミュレーション結果を示すグラフ。＊
＊【図２０】本発明による変形光源を用いたときの投影光学系の瞳面での光束分布を模式的に示す図。

【符号の説明】
１・・・・水銀ランプ
７、７Ａ～７Ｆ、７０Ａ～７０Ｄ・・・・フライアイレンズ
７０Ｅ～７０Ｈ・・・・オプチカルファイバー先端
８・・・・遮光板
１１・・・・コンデンサーレンズ
Ｒ・・・・レチクル
ＰＬ・・・・投影光学系
Ｗ・・・・ウェハ

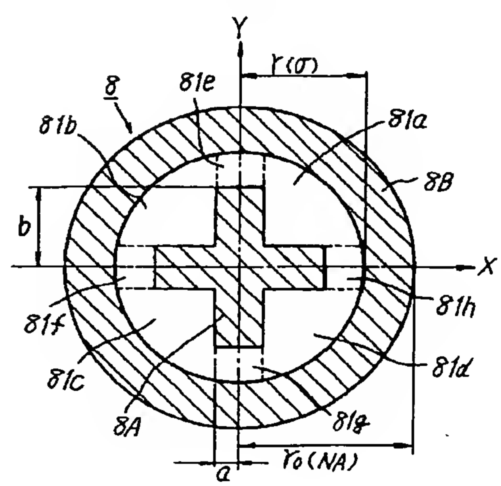
【図１】



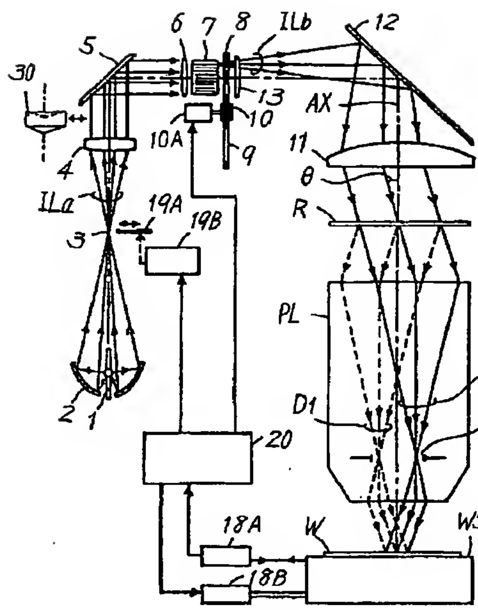
【図２】



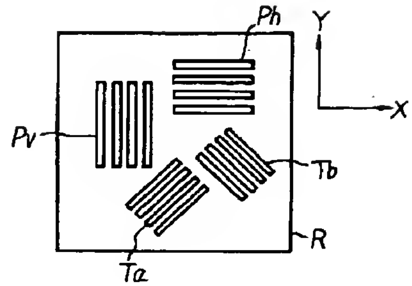
【図４】



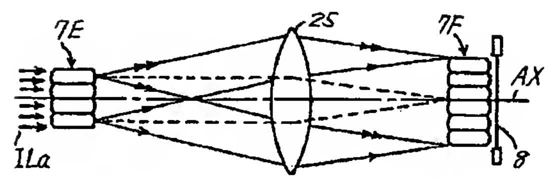
【図3】



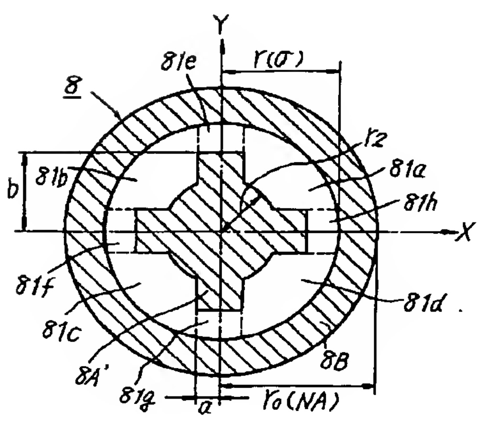
【図5】



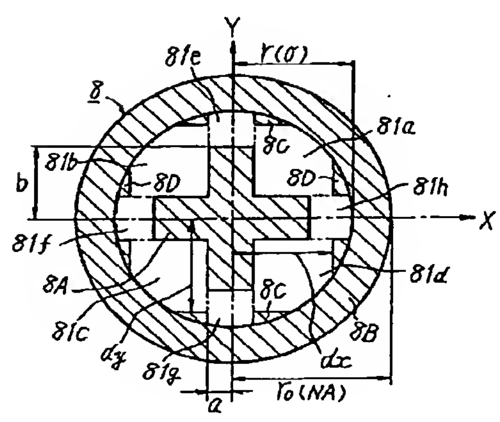
【図10】



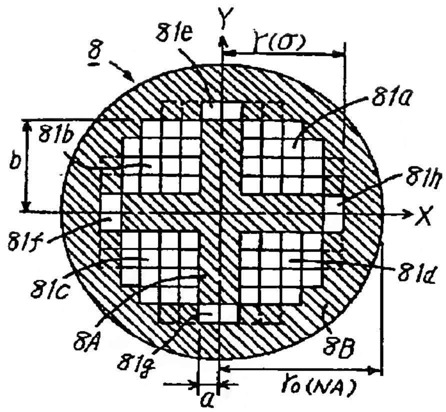
【図6】



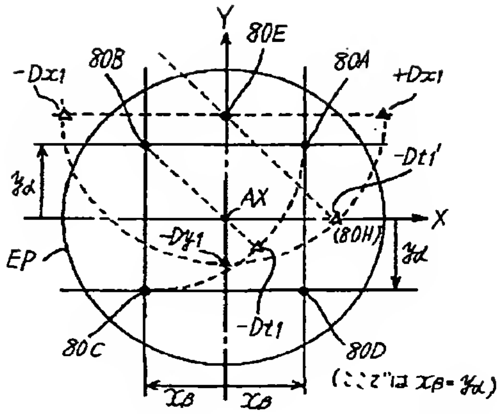
【図7】



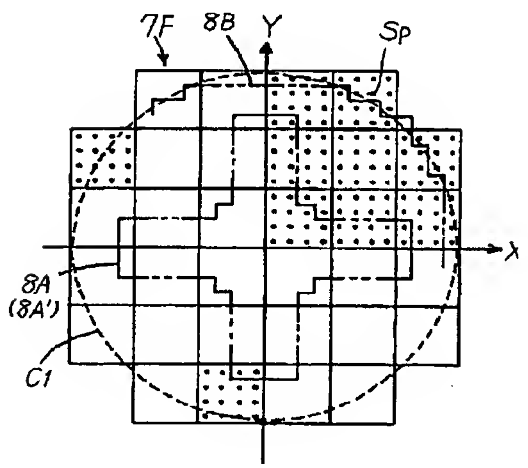
【図8】



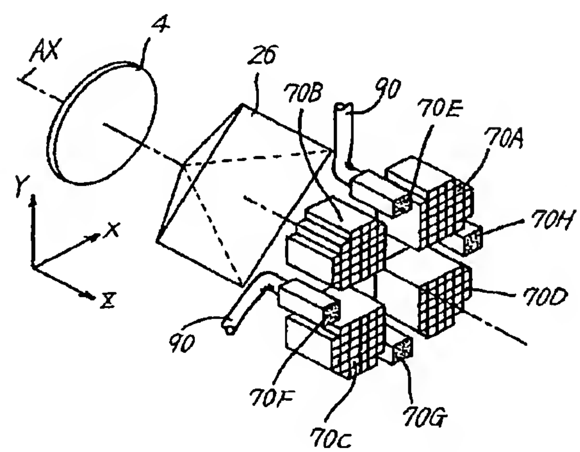
【図9】



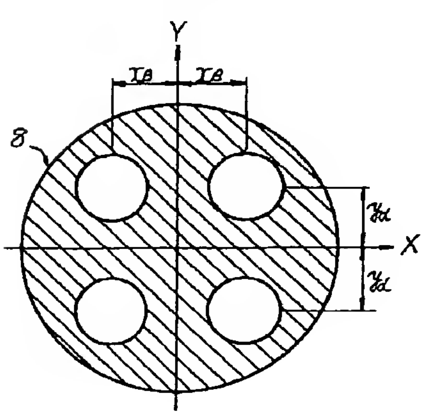
【図11】



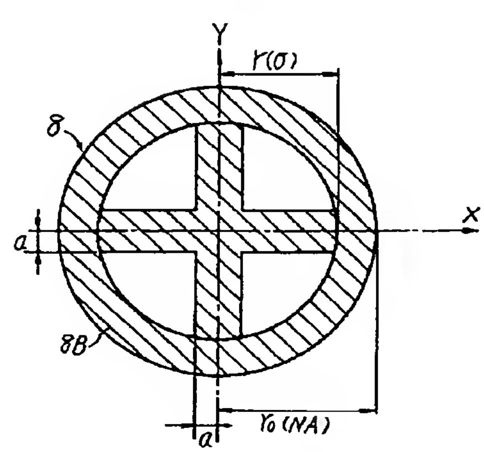
【図12】



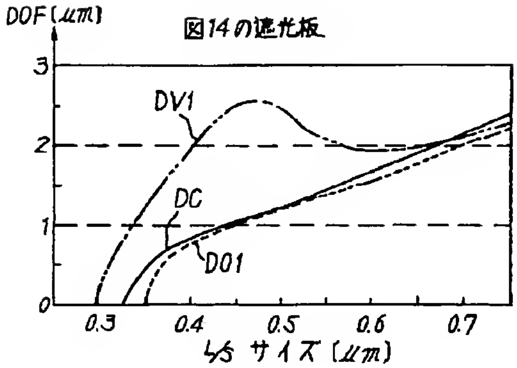
【図13】



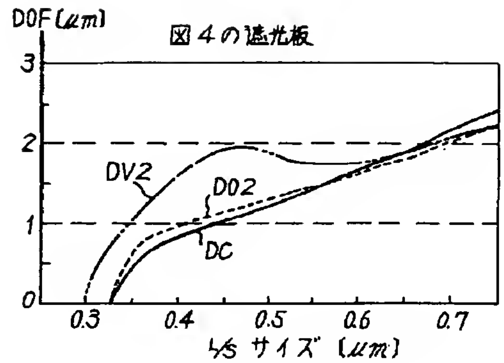
【図14】



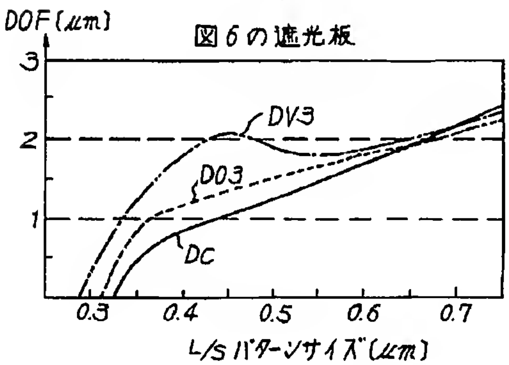
【図１５】



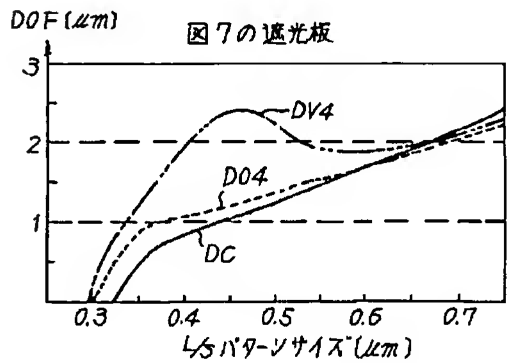
【図１６】



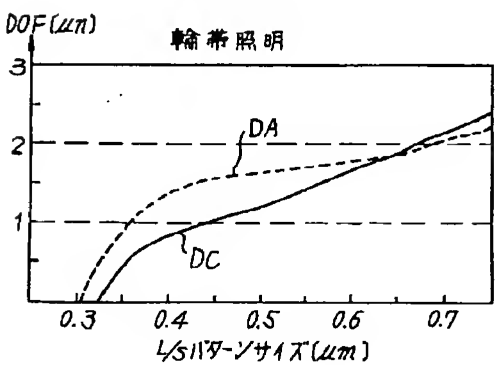
【図１７】



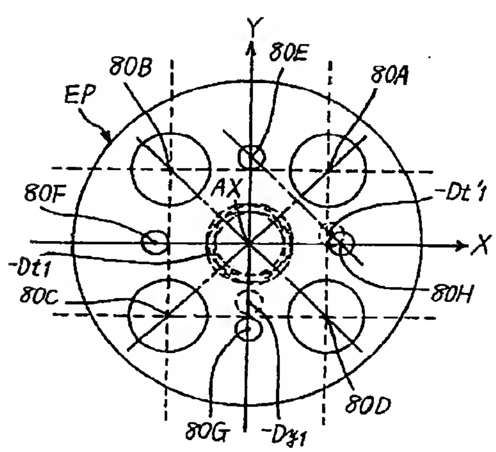
【図１８】



【図１９】



【図２０】



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【公報種別】特許法第１７条の２の規定による補正の掲載
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G03F 7/20 521
H01L 21/30 311 L

【手続補正書】
【提出日】平成１１年１２月２０日（１９９９．１２．２０）
【手続補正１】
【補正対象書類名】明細書
【補正対象項目名】発明の名称
【補正方法】変更
【補正内容】
【発明の名称】投影露光装置及び方法
【手続補正２】
【補正対象書類名】明細書
【補正対象項目名】特許請求の範囲
【補正方法】変更
【補正内容】
【特許請求の範囲】
【請求項１】投影すべきパターンが形成されたマスクを照明する照明系と、前記パターンの像を感光基板上に投影する投影光学系とを備えた投影露光装置において、
前記照明系は、前記マスクのパターン面に対して光学的にフーリエ変換の関係となる面を内部に有する照明光学系と、前記フーリエ変換面上、もしくはその近傍面上で光軸を中心とした所定半径内に照明光を分布させる光分布設定手段とを含み、
前記光分布設定手段は前記光軸を中心とした所定幅の輪帯状の領域内に前記照明光を分布させるとともに、前記輪帯状の領域の内側で中心部を除く離散的な複数の領域に前記照明光を分布させることを特徴とする投影露光装置。
【請求項２】前記パターンは、互いに直交する２方向にそれぞれ周期性を有する第１要素と、前記２方向と交差する方向に周期性を有する第２要素とを含み、前記複数の領域は、前記光軸を原点とし、かつ前記２方向に対応して規定される直交座標系で区画されることを特徴とする請求項１に記載の投影露光装置。
【請求項３】前記複数の領域は、前記光軸を中心として前記直交座標系上に規定される十字領域で区画され、前記フーリエ変換面上で見た前記投影光学系の瞳面の半径をr_o、前記十字領域の幅を２×ａ、長さを２×ｂとすると、$0.1r_o \leqq a \leqq 0.4r_o$、$0.4r_o \leqq b \leqq 0.8r_o$を満たすことを特徴とする請求項２に記載の投影露光装置。
【請求項４】前記中心部は円形であり、前記フーリエ変換面上で見た前記投影光学系の瞳面の半径をr_oとすると、前記中心部の半径$r2$は$0.3r_o \leqq r2 \leqq 0.4r_o$を満たすことを特徴とする請求項１～３のいずれか一項に記載の投影露光装置。
【請求項５】前記光分布設定手段は、前記複数の領域でそれぞれ外縁部の一部以外に前記照明光を分布させ、前記フーリエ変換面上で見た前記投影光学系の瞳面の半径をr_oとすると、前記外縁部の一部は前記直交座標系の座標軸との距離ｄが$0.5r_o < d < 0.8r_o$を満たすことを特徴とする請求項１～４のいずれか一項に記載の投影露光装置。
【請求項６】マスクに照射する照明光を発生する光源と、前記マスクのパターン面に対して光学的にフーリエ変換の関係となるフーリエ変換面、もしくはその近傍面に前記光源の２次光源を形成する照明光学系と、前記照明光学系からの照明光によって照射された前記マスクのパターンからの光を入射して、前記パターンの像を感光基板上に投影する投影光学系とを備えた投影露光装置に

おいて、
前記パターンが互いに直交する２方向にそれぞれ周期性を持つ第１要素と、前記２方向と交差する方向に周期性を持つ第２要素とを有し、かつ前記マスク上で前記第１要素の占める割合が前記第２要素の占める割合よりも多いとき、前記第１要素の周期方向に対応した傾斜照明光を作るように、前記フーリエ変換面、もしくはその近傍面上で前記照明光学系の光軸から偏心して互いに対称的に位置する４つの領域の夫々に第１の光源面を設定するとともに、前記第２要素の周期方向に対応した傾斜照明光を作るように、前記フーリエ変換面、もしくはその近傍面上で前記照明光学系の光軸から偏心して互いに対称的に位置する４つの領域の夫々に第２の光源面を設定する設定部材を備え、前記第１の光源面の面積を前記第２の光源面の面積よりも大きくしたことを特徴とする投影露光装置。

【請求項７】前記設定部材は、前記照明光学系のフーリエ変換面、もしくはその近傍面に配置された遮光板又は半透過板によって前記第１及び第２の光源面を規定したことを特徴とする請求項６に記載の投影露光装置。

【請求項８】マスク上で直交する２方向に周期性を持つ第１要素と、前記２方向と異なる方向に周期性を持つ第２要素とを含むパターンを感光基板上に投影する投影光学系と、光源からの光を入射して面光源を形成するとともに、前記面光源内の各点からの光を前記マスク上で重畳させる照明光学系とを備えた投影露光装置において、前記面光源の中心を原点として前記２方向に対応した２つの座標軸を設定するとき、前記２つの座標軸で規定される４つの象限の夫々にほぼ同一面積で形成される第１透過部と、前記原点からほぼ等距離で前記２つの座標軸上の夫々の４ヶ所に、ほぼ同一面積で形成される第２透過部とを有する遮光板を備え、前記第１及び第２要素の重要度に応じて前記第１透過部と前記第２透過部とでその面積を異ならせたことを特徴とする投影露光装置。

【請求項９】前記遮光板は、前記第１及び第２透過部以外が半透過部であることを特徴とする請求項８に記載の投影露光装置。

【請求項１０】前記第２要素から発生して前記投影光学系の瞳面の中央部に分布する回折光の光量を減衰させる減光フィルターを更に備えたことを特徴とする請求項８又は９に記載の投影露光装置。

【請求項１１】マスクのパターンを感光基板上に投影する投影光学系と、光源からの光を入射して、前記マスクに対する光学的なフーリエ変換面、もしくはその近傍面に面光源を形成し、前記面光源からの光を前記マスクに照射する照明光学系とを備えた投影露光装置において、前記面光源の中心を原点として直交座標系ＸＹを定め、前記面光源の外形に近似した円の半径をｒ、前記面光源のコヒーレンスファクターをσ値としたとき、係数ａ、ｂをそれぞれ$0.1r/\sigma \leqq a \leqq 0.4r/\sigma$、$0.4r/\sigma \leqq b \leqq 0.8r/\sigma$として、前記面光源上で$-a \leqq X \leqq a$、かつ$-b \leqq Y \leqq b$の領域内と$-a \leqq Y \leqq a$、かつ$-b \leqq X \leqq b$の領域内との光強度を他の領域よりも小さくするか、もしくはほぼ零にする光強度分布調整部材を設けたことを特徴とする投影露光装置。

【請求項１２】前記光強度分布調整部材は、係数ｃを$0.3r/\sigma \leqq c \leqq 0.6r/\sigma$としたとき、前記面光源上で、$X^2+Y^2 \leqq c^2$の領域内の光強度を他の領域よりも小さくするか、もしくはほぼ零とすることを特徴とする請求項１１に記載の投影露光装置。

【請求項１３】前記照明光学系は前記面光源の原点を前記投影光学系の瞳面の中心に結像するように構成され、前記投影光学系の実効的な瞳径の前記面光源上での半径をr_0としたとき、前記面光源の半径ｒとの比r/r_0である前記σ値を０．７以上にしたことを特徴とする請求項１１又は１２に記載の投影露光装置。

【請求項１４】前記パターンは透過部とハーフトーン透過部とで形成されることを特徴とする請求項１～１３のいずれか一項に記載の投影露光装置。

【請求項１５】照明光学系を通してマスクに照明光を照射するとともに、投影光学系を介して前記マスクのパターン像を感光基板上に投影する投影露光方法において、前記照明光学系内で前記マスクのパターン面に対して光学的にフーリエ変換の関係となる面上、もしくはその近傍面上で光軸を中心とした所定幅の輪帯状の領域内に前記照明光を分布させるとともに、前記輪帯状の領域の内側で中心部を除く離散的な複数の領域に前記照明光を分布させることを特徴とする投影露光方法。

【請求項１６】照明光学系を通してマスクに照明光を照射するとともに、投影光学系を介して前記マスクのパターン像を感光基板上に投影する投影露光方法において、前記照明光を、前記マスク上で直交する２方向に周期性を持つ第１要素と、前記２方向と異なる方向に周期性を持つ第２要素とを含むパターンに照射するとき、前記照明光学系内の前記マスクのパターン面に対する光学的なフーリエ変換面、もしくはその近傍面上で光軸を原点とする前記２方向に対応した直交座標系で規定される４つの象限の夫々に設定される第１領域、及び前記原点からほぼ等距離で前記直交座標系の座標軸上に設定される第２領域以外で光量を少なくする、もしくはほぼ零にするとともに、前記第１及び第２要素の重要度に応じて前記第１領域と前記第２領域とでその面積を異ならせることを特徴とする投影露光方法。

【請求項１７】照明光学系を通してマスクに照明光を照射するとともに、投影光学系を介して前記マスクのパターン像を感光基板上に投影する投影露光方法において、前記照明光学系内の前記マスクのパターン面に対する光学的なフーリエ変換面、もしくはその近傍面に形成される面光源の中心を原点として直交座標系ＸＹを定め、前記面光源の外形に近似した円の半径をｒ、前記面光源の